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A CALCULATION METHOD FOR CONVECTIVE HEAT AND MASS TRANSFER IN M--ETC(U)
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NO. 507

A CALCULATION METHOD FOR CONVECTIVE HEAT AND MASS TRANSFER IN MULTIPLY-SLOTTED FILM-COOLING APPLICATIONS (U)

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by

S.B. Murray

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A CALCULATION METHOD FOR CONVECTIVE HEAT AND MASS TRANSFER IN MULTIPLY-SLOTTED FILM-COOLING APPLICATIONS (U)

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ABSTRACT

A computer model to calculate the development of wall jet boundary layers downstream of multiple film-cooling slots is described. The differential equations for the conservation of mass, momentum and energy in an incompressible two-dimensional or axisymmetric flow are solved using a downstream-marching, iterative, implicit, finite-difference scheme. The turbulent transport of mass in a conventional wall boundary layer is described by means of an inner-outer two-layer eddy-viscosity model based on the Prandtl mixing-length hypothesis with Van Driest's modification in the near-wall region. Further alterations to include the effects of pressure gradients, heat and mass transfer are due to Cebeci and Smith. This basic model is extended to include cases with tangential fluid injection.

Computed velocity profiles indicate that the law of the wall is >next page

ABSTRACT (Cont'd)

obeyed in the inner layer and that the outer wake-like layer strives to resume the velocity-defect relationship that existed upstream of the point of fluid injection in zero pressure-gradient flow with no heat or mass transfer.

Comparison between computed and experimental adiabatic wall temperature distributions in flows with heat transfer shows that the eddy-viscosity model is deficient in the near-slot region and tends to overestimate film-cooling efficiency. The absence of an eddy term to account for turbulence due to finite slot lip thickness is partly responsible for this overestimation.

Recommendations are made to validate the model in pressure-gradient flows and to improve the predictive capability in the near-slot region.

(U)

NOMENCLATURE

Symbols

a denotes functional relationship in dimensionless velocity-profile expression.

A is Van Driest's damping-length parameter or a coefficient of $u_{m,n-1}$ in the tridiagonally-banded system of equations.

b is a constant in the dimensionless velocity-profile expression.

B is a coefficient of $u_{m,n}$ in the tridiagonally-banded system of equations.

C is a coefficient of $u_{m,n+1}$ in the tridiagonally-banded system of equations.

d_1 is the injection slot width.

d_2 is the injection slot length.

D is the constant term in the tridiagonally-banded system of equations.

f denotes a functional relationship.

g_c is a constant in the momentum equation.

H is the height of the finite-difference grid in the y-direction.

ℓ is the mixing length.

L is the distance in the x-direction from the injection slot entrance to the downstream end of the finite-difference grid.

m is a dimensionless mass-flow parameter in Mukherjee's correlation, or m is the streamwise station number in the finite-difference grid.

M is the total number of streamwise stations in the finite-difference grid.

n is the transverse station number in the finite-difference grid.

N is a parameter to account for pressure-gradient, heat and mass transfer effects in Van Driest's modification to the mixing length in the near-wall region, or N is the total number of transverse stations in the finite-difference grid.

NOMENCLATURE - Symbols (cont'd)

p is static pressure.

p^+ is a dimensionless pressure-gradient parameter.

Pr is the molecular Prandtl number.

Pr_t is the turbulent Prandtl number

q is an arbitrary parameter that is a function of x and y.

r is the local radius in axisymmetric flow.

R is the gas constant for main and injected streams.

Re_2 is Reynolds number based on the injection slot width and mean injection velocity.

T is static temperature.

T' is the fluctuating component of static temperature, or T' is static temperature from a previous iteration or station.

u is the streamwise component of fluid velocity.

u' is the fluctuating component of streamwise velocity.

v is the transverse component of fluid velocity.

v' is the fluctuating component of transverse velocity.

v_w is the velocity of fluid being transferred across the wall.

v_w^+ is a dimensionless mass-transfer parameter.

w is the thickness of the slot lip.

x is the streamwise coordinate (measured along the wall).

Δx is the streamwise grid interval.

y is the transverse coordinate (measured normal to the wall).

Δy is a characteristic transverse grid interval.

Δy_1 is the transverse grid interval in the grid zone closest to the wall. That is $\Delta y_1 = \Delta y$ for $0 \le y \le d_1/2$.

NOMENCLATURE - Symbols (cont'd)

Δy_2 is the transverse grid interval in the intermediate grid zone. That is $\Delta y_2 = 10\ \Delta y$ for $d_1/2 \leq y \leq 2d_1$.

Δy_3 is the transverse grid interval in the outer grid zone. That is $\Delta y_3 = 100\ \Delta y$ for $2d_1 \leq y \leq H$.

α is the molecular thermal conductivity.

α_t is the eddy the al conductivity.

β is the nondimensional distance in Mukherjee's film-cooling correlation.

δ is the boundary-layer thickness.

η is the film-cooling efficiency in Mukherjee's film-cooling correlation.

κ is von Karman's mixing-length constant (equal to 0.435 in this report).

λ is a proportionality constant relating the mixing length in the outer region to boundary-layer thickness.

μ is molecular dynamic viscosity.

ν is molecular kinematic viscosity.

ν_t is eddy (kinematic) viscosity.

ρ is static density.

τ is local shear stress.

Subscripts

e is in reference to the edge of the boundary layer.

w depicts a value at the wall.

1 refers to the condition of the hot gas or main-stream fluid.

2 denotes the condition of the cooling air or injected fluid.

Superscripts

k is zero for plane flow and unity for axisymmetric flow.

+ refers to dimensionless quantities.

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A CALCULATION METHOD FOR CONVECTIVE HEAT AND MASS TRANSFER IN MULTIPLY-SLOTTED FILM-COOLING APPLICATIONS (U)

by

S.B. Murray

1. INTRODUCTION

This report describes a computer model intended for use in the calculation of wall jet boundary layers downstream of multiple film-cooling slots. This model was developed at DRES as part of work to determine specifications for future military acquisitions.

Both at the time the project began and at time of writing the author is not aware of any computer model that is available, either commercially or through governmental sources, that fulfills the particular requirements, in part or in full, of the present application. Although the theory of turbulent flows has been a subject of interest for several decades, from the point of view of commercial software, the development of application packages is still in its infancy. For this reason, the author elected to write a special purpose program in order to meet the specific requirements of the aforementioned studies.

Briefly, the model is applicable to incompressible, turbulent wall jet boundary layers with pressure-gradient, heat-transfer and mass-transfer effects in flows over two-dimensional or axisymmetric bodies with multiple film-cooling slots. For the engineering nature of the present work a relatively simple mixing model and differencing scheme have been employed. The theoretical model is described in Section 2 and details regarding the solution procedure are outlined in Section 3. Comparisons of prediction to experiment are presented in Section 4. Documented listings and a description of the program are included in Appendix A, while a user's guide and sample run appear in Appendix B.

2. THE THEORETICAL MODEL

The theory described in this report is based on numerical solution of the two-dimensional or axisymmetric, turbulent boundary-layer equations using a downstream-marching, iterative, implicit, finite-difference method. The turbulent transport terms in the boundary-layer equations are described by means of a two-layer eddy-viscosity model intended for use in the calculation of conventional turbulent wall boundary layers. This model has been extended to cases with tangential fluid injection.

2.1 The Governing Boundary-Layer Equations

The present calculations employ the incompressible turbulent boundary-layer equations in terms of time-averaged mean-flow quantities. For flow about two-dimensional and axisymmetric bodies at high Reynolds number the governing equations are:

Continuity

$$\frac{\partial}{\partial x}(r^k \rho u) + \frac{\partial}{\partial y}(r^k \rho v) = 0 \qquad (1)$$

x-Momentum

$$u\frac{\partial u}{\partial x} + v\frac{\partial u}{\partial y} = -\frac{g_c}{\rho}\frac{dp}{dx} + \frac{1}{r^k \rho}\frac{\partial}{\partial y}\left\{r^k\left[\mu\frac{\partial u}{\partial y} - \rho\overline{u'v'}\right]\right\} \qquad (2)$$

Energy

$$u\frac{\partial T}{\partial x} + v\frac{\partial T}{\partial y} = \frac{1}{r^k \rho}\frac{\partial}{\partial y}\left\{r^k\left[\frac{\mu}{Pr}\frac{\partial T}{\partial y} - \rho\overline{T'v'}\right]\right\} \tag{3}$$

State

$$p = \rho RT \tag{4}$$

with the following Boussinesq eddy-diffusivity assumptions for the Reynolds stress and heat-transfer terms:

$$\left.\begin{aligned} -\rho\overline{u'v'} &= \rho\nu_t \frac{\partial u}{\partial y} \\ -\rho\overline{T'v'} &= \rho\alpha_t \frac{\partial T}{\partial y} \end{aligned}\right\} \tag{5}$$

The exponent k is equal to zero for plane flow and equal to unity for axisymmetric flow. The coordinate system, shown in Figure 1, is curvilinear in which x and y are distances along and normal to the body surface, with u and v the velocity components within the boundary layer in the x- and y-directions, respectively. The static pressure, p, is assumed to be independent of y with quantities T, ρ and μ being the local fluid temperature, density and dynamic viscosity, respectively. The eddy viscosity, ν_t, and eddy thermal conductivity, α_t, are related by the turbulent Prandtl number:

$$Pr_t = \frac{\nu_t}{\alpha_t} \ . \tag{6}$$

The boundary conditions associated with the above equations are:

Momentum

$$\left.\begin{aligned} u(x,0) &= 0, \\ v(x,0) &= v_w \quad \text{and} \\ \lim_{y\to\infty} u(x,y) &= u_e(x) \end{aligned}\right\} \tag{7}$$

Energy

$$\left.\begin{aligned} T(x,0) &= T_w \quad \text{or} \\ \frac{\partial T}{\partial y}(x,0) &= \frac{\partial T}{\partial y}_w \quad \text{and} \\ \lim_{y\to\infty} T(x,y) &= T_e(x) \end{aligned}\right\} \quad (8)$$

where subscripts w and e denote conditions at the wall and at the outer edge of the boundary layer, respectively. These equations fulfill the requirements of no slip or mass injection at the wall as well as pre-cribing the streamwise distribution of either wall temperature or heat flux. The outer edge velocity, $u_e(x)$, and static temperature, $T_e(x)$, are obtained from experiment or an inviscid flow calculation and must be consistent with the streamwise distribution of static pressure, p(x).

2.2 The Turbulent Transport of Momentum

Shear stress in a conventional turbulent wall boundary layer is treated herein by the use of a two-layer eddy-viscosity model based on Prandtl's mixing-length hypothesis and employing a modified version of Van Driest's (1956) analysis in the near-wall region.

2.2.1 The inner region

In the inner region, where response to changes in energy supply is immediate, the eddy viscosity is given by:

$$\nu_t = \kappa^2 y^2 [1 - \exp(-y/A)]^2 \left|\frac{\partial u}{\partial y}\right| \quad (9)$$

where κ is von Karman's mixing-length constant, equal to 0.435, and A is Van Driest's damping-length parameter, $26\nu(\tau_w/\rho)^{-\frac{1}{2}}$. Here τ_w is the wall shear stress and ν is the local fluid kinematic viscosity. Van Driest's modification results in a continuous distribution of shear stress from the laminar value in the viscous sublayer, through the transition layer where laminar and turbulent components of shear stress are comparable, and out into the fully turbulent layer.

As it stands, Equation 9 is applicable to incompressible boundary layers with negligible pressure-gradient and heat-transfer effects and zero mass transfer. By following Van Driest's modelling of the viscous sublayer Cebeci and Smith (1974) have generalized the damping-length parameter to account for these variations. In their formulation this parameter is given by:

$$A = \frac{26\nu}{N}\left(\frac{\tau_w}{\rho_w}\right)^{-\frac{1}{2}}\left(\frac{\rho}{\rho_w}\right)^{\frac{1}{2}} \qquad (10)$$

where N is a factor defined below.

For flows with no mass transfer:

$$N = \left\{1 - 11.8\left(\frac{\mu_w}{\mu_e}\right)\left(\frac{\rho_e}{\rho_w}\right)^2 p^+\right\}^{\frac{1}{2}} \qquad (11)$$

When mass transfer effects are included:

$$N = \left\{\frac{\mu}{\mu_e}\left(\frac{\rho_e}{\rho_w}\right)^2 \frac{p^+}{v_w^+}\left[1 - \exp\left(11.8\frac{\mu_w}{\mu}v_w^+\right)\right] + \exp\left(11.8\frac{\mu_w}{\mu}v_w^+\right)\right\}^{\frac{1}{2}} \qquad (12)$$

The dimensionless pressure-gradient and mass-transfer parameters, p^+ and v_w^+, are defined by:

$$p^+ = -\frac{\nu_e}{u_\tau^3}\cdot\frac{g_c}{\rho_e}\frac{dp}{dx} \qquad \text{and} \qquad (13)$$

$$v_w^+ = \frac{v_w}{u_\tau} \qquad (14)$$

where u_τ is the friction velocity at the wall, $(\tau_w/\rho_w)^{\frac{1}{2}}$, and v_w is the velocity of the fluid which is being transferred across the wall.

2.2.2 The outer region

In the outer wake-like region of a conventional turbulent boundary layer the characteristic time scale of the flow is very much larger than that of the inner region. Ideally, the calculations should account for long turbulence decay times so that the distribution of eddy

viscosity at any particular streamwise location depends on the upstream development of the outer layer.

One particularly accurate model for this region, based on the experimental findings of Wygnanski and Fiedler (1968) about the concept of intermittency, is presented by Dvorak (1973). His approach correlates the development of the outer region with conventional boundary-layer parameters such as the displacement thickness, δ^*, and shape factor, H. Unfortunately, this model is not very well suited to flows with large density gradients typical of the present application, since δ^* and H take on values which are outside the range over which the experimental data of the above researchers is valid. As a result, since implementation of the model at present is in support of film-cooling design, the approach due to Dvorak has been abandoned.

One suitable alternative is to employ the mixing-length theory but with a mixing-length formulation representative of the activity in the outer wake-like portion of the layer. Whereas the mixing length in the inner region is proportional to distance from the wall, Escudier (1965) suggests that in the outer region the mixing length should be proportional to the overall boundary layer thickness so that:

$$\ell = \lambda\delta \qquad \text{and}$$

$$\nu_t = \lambda^2\delta^2\left|\frac{\partial u}{\partial y}\right| \quad \text{for} \quad \frac{\lambda\delta}{} \le y \le \delta \, . \qquad (15)$$

Patankar and Spalding (1968) recommend values for λ and κ of 0.09 and 0.435, respectively. For $y \le \lambda\delta/\kappa$ the inner-layer model of Equation 9 (with Cebeci and Smith's modifications) is applied.

2.2.3 Extension to tangential injection

The eddy-viscosity model just presented is intended for use in the calculation of conventional wall boundary layers. In the present work, it has been extended to include tangential fluid injection in a manner similar to that of Pai and Whitelaw (1970) and that of Dvorak.

As shown in Figure 2, there are two distinct types of wall jet boundary layers for the purpose of the present discussion. In case 1,

the wall jet does not possess enough momentum to completely entrain the remnant of the main-stream boundary layer. This gives rise to a velocity profile with a local jet maximum and a distinct velocity minimum. In case 2, the wall jet has sufficient momentum to consume this layer completely. The resulting velocity profile exhibits a wall jet maximum but no velocity minimum.

In order to construct an eddy-viscosity profile which is consistent with a given velocity distribution, it is assumed that as long as a wall jet maximum is present, the jet region and the remnant of the main-stream boundary layer behave as independent entities. The simple two-layer model presented in 2.2.1 and 2.2.2 is used to formulate the eddy-viscosity profile in the wall jet, starting at the wall and working outward into the fully turbulent region. The boundary-layer thickness used in this calculation is simply the distance from the wall to the point where the velocity maximum exists. Since the eddy viscosity is zero both at the wall (where $y = 0$) and at the point of maximum velocity (where $du/dy = 0$), it must pass through a maximum somewhere between these points. This will be referred to as maximum 1.

In a similar manner, the simple two-layer model is used to configure the eddy-viscosity distribution in the remnant of the main-stream boundary layer, starting in the free stream and working toward the wall. The boundary layer thickness employed in this computation is the distance from the wall to the point at the outer edge of the boundary layer where the velocity equals 99 percent of that in the free stream. In these calculations the eddy viscosity is zero at the outer edge (where $du/dy = 0$) and passes through a local maximum before returning to zero at a point (where $du/dy = 0$) defined as follows:

Case 1: the location of velocity minimum; and

Case 2: the location of wall jet local velocity maximum.

This eddy-viscosity maximum will be referred to as maximum 2.

As emphasized by Pai and Whitelaw, Launder and Spalding (1972) and Dvorak, strict application of the mixing-length hypothesis between

eddy-viscosity maxima 1 and 2 creates problems in that some gradients tend to infinity. To avoid this occurrence, Pai and Whitelaw simply fit a straight-line "bridge" between maxima. The approach of Dvorak, and the one taken here, is to fit a cosine fairing between maxima to make the eddy-viscosity profile continuous over the bridged region.

2.3 The Turbulent Transport of Heat

Before the temperature distribution within a boundary layer can be predicted, it is necessary to prescribe the distribution of thermal conductivity, α_t, for use in Equation 5. The most common and extensively used hypothesis is that due to Reynolds who assumed that heat and momentum are transferred by the same mechanism. With this assumption the eddy coefficients for momentum and heat transport are identical and yield a turbulent Prandtl number of unity.

For the purpose of predicting heat transport in film-cooling, however, an approach that has met with remarkable success is that of Kacker, Pai and Whitelaw (1969). These researchers used experimental data to derive an empirical Prandtl number distribution of the form:

$$Pr_t = 1.75 - 1.25(y/\delta) \quad \text{for} \quad 0 \le y/\delta \le 1 \quad \text{and}$$
$$Pr_t = 0.5 \quad \text{for} \quad y/\delta \ge 1. \tag{16}$$

In the present study, this Prandtl number distribution is used in conjunction with the eddy-viscosity model of 2.2 to arrive at a suitable eddy-conductivity profile for use in solving the energy equation.

3. THE SOLUTION PROCEDURE

3.1 The Finite-Difference Grid Network

The grid network that is used to discretize the flow field downstream of the injection slot is shown for an arbitrary case in Figure 3. Cooling air enters the slot of width d_1 and is directed a distance d_2 in the downstream direction before emerging from the slot to interact with the main stream. The wall which separates the secondary and primary flows is of thickness w. A constant grid interval of Δx is employed in the stream-

wise direction between $x = d_2$ and $x = L$. In the y-direction, where the characteristic scale of turbulence changes markedly with increasing distance from the wall, a three-zone grid spacing is used. In film-cooling or other studies involving slot blowing it seems particularly appropriate to choose grid intervals and grid zone boundaries as follows:

$$\Delta y_1 = \Delta y' \quad \text{for} \quad 0 \le y \le d_1/2,$$

$$\Delta y_2 = 10\,\Delta y' \quad \text{for} \quad d_1/2 \le y \le 2d_1 \text{ and}$$

$$\Delta y_3 = 100\,\Delta y' \quad \text{for} \quad 2d_1 \le y \le H,$$

where $\Delta y'$ is some appropriately small distance in comparison to the viscous sublayer thickness.

3.2 The Finite-Difference Equations

Since the theoretical models used to describe the turbulent transfer of mass and heat in this application are not among the most sophisticated available, there is no need to utilize a high order finite-difference scheme. In the present calculations three-point central differencing in the y-direction and three-point upstream differencing in the x-direction will suffice. With this order of differencing, first and second partial derivatives of any variable q with respect to y are approximated by:

$$\frac{\partial q}{\partial y} \doteq \frac{q_{m,n+1} - q_{m,n-1}}{2\Delta y} \quad \text{and}$$

$$\frac{\partial^2 q}{\partial y^2} \doteq \frac{q_{m,n+1} - 2q_{m,n} + q_{m,n-1}}{\Delta y^2}$$

at a given point (m,n) in the interior of the grid. Similarly, the first partial derivative with respect to x of the same function at that point is approximated by:

$$\frac{\partial q}{\partial x} \doteq \frac{3q_{m,n} - 4q_{m-1,n} + q_{m-2,n}}{2\Delta x} .$$

3.2.1 The momentum equation in finite-difference form

With these approximations the left side of the momentum equation (Equation 2) becomes:

$$u\frac{\partial u}{\partial x} + v\frac{\partial u}{\partial y} \doteq u'_{m,n}\left[\frac{3u_{m,n} - 4u_{m-1,n} + u_{m-2,n}}{2\Delta x}\right] + v'_{m,n}\left[\frac{u_{m,n+1} - u_{m,n-1}}{2\Delta y}\right]$$

where $u'_{m,n}$ and $v'_{m,n}$ are the values of $u_{m,n}$ and $v_{m,n}$ from the previous iteration. The use of these previously-computed quantities is necessary for two reasons. Firstly, the presence of $u'_{m,n}$ above eliminates what would otherwise be a second order term in $u_{m,n}$, thus complicating the solution procedure. Secondly, current values of transverse velocity $v_{m,n}$ are not available for the solution of the momentum equation since these are calculated by integrating the continuity equation once the distribution of streamwise velocity is known. Hence the transverse velocity from the previous iteration $v'_{m,n}$ is used. Since the distributions of eddy viscosity and streamwise velocity must be made consistent through iteration anyway, the use of these previously-computed quantities does not necessitate any additional iteration. Note that as consistency between eddy viscosity and streamwise velocity occurs $u'_{m,n}$ and $v'_{m,n}$ will approach $u_{m,n}$ and $v_{m,n}$, respectively.

Applying the chain rule to the right side of the momentum equation and expressing it in finite-difference form gives:

$$-\frac{g_c}{\rho}\frac{dp}{dx} + \frac{1}{r^k\rho}\frac{\partial}{\partial y}\left\{r^k\rho\,(\nu + \nu_t)\frac{\partial u}{\partial y}\right\}$$

$$\doteq \frac{-g_c}{\rho_{m,n}}\left[\frac{3p_m - 4p_{m-1} + p_{m-2}}{2\Delta x}\right] + (\nu + \nu_t)_{m,n}\left[\frac{u_{m,n+1} - 2u_{m,n} + u_{m,n-1}}{\Delta y^2}\right]$$

$$+ \left[\frac{u_{m,n+1} - u_{m,n-1}}{2\Delta y}\right]\left[\frac{(\nu + \nu_t)_{m,n+1} - (\nu + \nu_t)_{m,n-1}}{2\Delta y}\right]$$

$$+ \frac{(\nu + \nu_t)_{m,n}}{\rho_{m,n}}\left[\frac{u_{m,n+1} - u_{m,n-1}}{2\Delta y}\right]\left[\frac{\rho_{m,n+1} - \rho_{m,n-1}}{2\Delta y}\right]$$

$$+ \frac{(\nu + \nu_t)_{m,n}}{r^k_{m,n}} \left[\frac{u_{m,n+1} - u_{m,n-1}}{2\Delta y} \right] \left[\frac{r^k_{m,n+1} - r^k_{m,n-1}}{2\Delta y} \right]$$

Equating left and right sides and gathering like terms gives:

$$Au_{m,n-1} + Bu_{m,n} + Cu_{m,n+1} = D \tag{16}$$

where
$$A = 2v'_{m,n}\Delta y - (\nu + \nu_t)_{m,n+1} + (\nu + \nu_t)_{m,n-1} + (\nu + \nu_t)_{m,n} \left\{ 4 - \frac{\rho_{m,n+1} - \rho_{m,n-1}}{\rho_{m,n}} - \frac{r^k_{m,n+1} - r^k_{m,n-1}}{r^k_{m,n}} \right\},$$

$$B = - \frac{6u'_{m,n}\Delta y^2}{\Delta x} - 8\,(\nu + \nu_t)_{m,n},$$

$$C = - 2v'_{m,n}\Delta y + (\nu + \nu_t)_{m,n+1} - (\nu + \nu_t)_{m,n-1} + (\nu + \nu_t)_{m,n} \left\{ 4 + \frac{\rho_{m,n+1} - \rho_{m,n-1}}{\rho_{m,n}} + \frac{r^k_{m,n+1} - r^k_{m,n-1}}{r^k_{m,n}} \right\}, \text{ and}$$

$$D = 2u'_{m,n}\Delta y^2 \left\{ \frac{u_{m-2,n} - 4u_{m-1,n}}{\Delta x} \right\} + \frac{2g_c\Delta y^2}{\rho_{m,n}} \left\{ \frac{3p_m - 4p_{m-1} + p_{m-2}}{\Delta x} \right\}.$$

The above coefficients are valid for all N points at a given streamwise station with the exception of those two points at the interface between grid zones and those two points at the wall and free-stream boundaries.

The criterion used to evaluate the coefficients at the grid-zone boundaries is one of equal velocity profile first derivatives (i.e., identical slopes). The wall boundary condition, namely that $u_w = 0$, is easily imposed by setting the B coefficient to unity and all others to zero. Likewise, the free-stream boundary condition is fixed by setting the B coefficient to unity, the D coefficient to u_e and all others to zero. The boundary conditions, in terms of these coefficients, are summarized in Table I below.

Boundary Condition	Coefficient			
	A	B	C	D
wall boundary	0	1	0	0
free-stream boundary	0	1	0	u_e
grid-zone interface	10	- 11	1	0

Table I: Coefficients for Use in Equation 16 to Depict Boundary Conditions for the Momentum Equation.

With the aid of these boundary conditions Equation 16 is written for all points at a given streamwise station to form a system of N algebraic equations in tridiagonally-banded form (which is solvable by rapid means).

3.2.2 The continuity equation in finite-difference form

Having solved the momentum equation the distribution of streamwise velocity is known. Values of transverse velocity can now be computed by integrating the continuity equation. In finite-difference form Equation 1 is written at any point (m,n-½) using three-point differencing to yield the transverse velocity at point (m,n):

$$v_{m,n} = \frac{(r^k\rho v)_{m,n-1} - \Delta y \frac{\partial}{\partial x}(r^k\rho u)_{m,n-\frac{1}{2}}}{(r^k\rho)_{m,n}}$$

where $\frac{\partial}{\partial x}(r^k\rho u)_{m,n-\frac{1}{2}} = \frac{1}{2}\left(\frac{\partial}{\partial x}(r^k\rho u)_{m,n-1} + \frac{\partial}{\partial x}(r^k\rho u)_{m,n}\right)$.

The streamwise derivatives are evaluated using the three-point upstream differencing formulation presented earlier.

Starting at the wall where $v_{m,1}$ is either zero or specified by a boundary-layer bleed relationship, the above equation is written at (m,1½) in order to compute $v_{m,2}$. It is then written at (m,2½) to give $v_{m,3}$, and so on, until $v_{m,n}$ is known for all $1 \le n \le N$.

3.2.3 The energy equation in finite-difference form

The energy equation (Equation 3) is of a form identical to that of the momentum equation with the pressure-gradient term omitted. Consequently, the differential equation reduces to a system of linear algebraic equations in tridiagonally-banded form as did the momentum equation. The coefficients in this case are:

$$A = 2v_{m,n}\Delta y - (\alpha + \alpha_t)_{m,n+1} + (\alpha + \alpha_t)_{m,n-1}$$

$$+ (\alpha + \alpha_t)_{m,n}\left\{4 - \frac{\rho_{m,n+1} - \rho_{m,n-1}}{\rho_{m,n}} - \frac{r^k_{m,n+1} - r^k_{m,n-1}}{r^k_{m,n}}\right\},$$

$$B = -\frac{6u_{m,n}\Delta y^2}{\Delta x} - 8(\alpha + \alpha_t)_{m,n} \quad ,$$

$$C = -2v_{m,n}\Delta y + (\alpha + \alpha_t)_{m,n+1} - (\alpha + \alpha_t)_{m,n-1}$$

$$+ (\alpha + \alpha_t)_{m,n}\left\{4 + \frac{\rho_{m,n+1} - \rho_{m,n-1}}{\rho_{m,n}} + \frac{r^k_{m,n+1} - r^k_{m,n-1}}{r^k_{m,n}}\right\}, \text{ and}$$

$$D = 2u_{m,n}\Delta y^2\left\{\frac{T_{m-2,n} - 4T_{m-1,n}}{\Delta x}\right\}$$

with boundary conditions as given in Table II below.

Boundary Condition	Coefficient			
	A	B	C	D
wall boundary	0	1	0	T_w
free-stream boundary	0	1	0	T_e
grid-zone interface	10	- 11	1	0

Table II: Coefficients for Use in Equation 16 to Depict Boundary Conditions for the Energy Equation.

The wall temperature, T_w, may be specified explicitly or in an implicit fashion such as a temperature-gradient boundary condition (which is more difficult to handle). The latter is particularly common when radiative heat transfer is taking place between the wall and another body. In order to solve the temperature-gradient case without making the algebraic equations non-linear, a guess is made at the wall temperature and the corresponding radiative heat flux is computed. This flux fixes the temperature gradient at the wall, thereby yielding a solution to the system of algebraic equations which represent the differential energy equation. Once a solution is generated the validity of first guess becomes apparent and, if necessary, the procedure is repeated until convergence on wall temperature is achieved.

3.3 The Downstream-Marching Iterative Solution Procedure

The system of parabolic differential Equations (1) through (3) with the turbulent momentum and heat transport assumptions of Sections 2.2 and 2.3 is solved using a downstream-marching, iterative, finite-difference solution algorithm. Three-point upstream differencing with downstream marching allows the velocity, temperature, eddy-viscosity and eddy-conductivity profiles to be computed at successive streamwise locations using information from only the two neighbouring upstream stations. For the purpose of starting the calculations, certain information (such as boundary layer thickness, free-stream and jet velocities and temperatures, etc.) is supplied by the user and utilized with formulations such as the "law of the wall" and Coles' (1956) "law of the wake" to construct upstream velocity and temperature profiles.

A flow chart describing the iterative solution procedure appears in Figure 4. Upon arriving at a new streamwise location, the first step is to assume a temperature profile, $T(y)$, at that station. This is readily done through extrapolation with the aid of temperature profiles from upstream locations. In conjunction with the static pressure, $p(x)$, this temperature distribution is used to compute density, dynamic-viscosity and kinematic-viscosity profiles, $\rho(y)$, $\mu(y)$ and $\nu(y)$, respectively. Next, in a manner identical to that above, assumptions must be made about the

distributions of both streamwise and transverse components of velocity, $u(y)$ and $v(y)$, respectively. Once these profiles are established, a corresponding eddy-viscosity profile, $\nu_t(y)$, is easily computed using the theoretical model presented in Section 2.2 along with the velocity gradient, $\partial u/\partial y$. The momentum equation can now be solved using the distributions of transverse velocity and eddy viscosity to yield a new streamwise velocity profile, $u'(y)$. The continuity equation then dictates a new transverse velocity profile, $v'(y)$. If these profiles are not in agreement with those that were initially assumed, $u(y)$ and $v(y)$ are replaced by $u'(y)$ and $v'(y)$ and the procedure is repeated until $u(y)$, $v(y)$ and $\nu_t(y)$ become consistent.

Once the above profiles are refined through convergence the energy equation is tackled. An eddy-conductivity profile, $\alpha_t(y)$, is calculated from the eddy-viscosity profile and assumptions about the turbulent Prandtl number, as presented in Section 2.3. This eddy-conductivity profile, along with the distributions of streamwise and transverse velocity computed above, is used to solve the energy equation for a new temperature profile, $T'(y)$. If it agrees with the initial assumption, $T(y)$, calculations at the streamwise station in question are now complete. If agreement is not achieved, then $T(y)$ is replaced by $T'(y)$ and calculations at this station are performed again from the start, including those for $u(y)$, $v(y)$ and $\nu_t(y)$.

A documented program listing and description of variables appear in Appendix A. A user's guide is presented in Appendix B.

4. RESULTS AND DISCUSSION

The applicability of Prandtl's mixing-length hypothesis to wall jet flows with heat transfer need not be questioned as this has been the subject of many research projects in the past. What is of importance presently is to ensure that this hypothesis has been incorporated correctly into the computer model.

One of the most reliable checks is to plot computed velocity profiles in the form u/u_τ versus $u_\tau y/\nu$ in order to examine the near-wall and law of the wall regions of the boundary layer. Figure 5 shows six

profiles plotted in this manner for the case of zero pressure-gradient flow with no heat or mass transfer. Two profiles at various streamwise locations, x/d_1, are plotted for each of three nominal velocity ratios, u_2/u_1. The solid line shows the velocity profile obtained by integrating the shear stress equation over the region of constant stress with the Prandtl mixing-length formula characterizing the turbulent component. With these assumptions the velocity profile is of the form:

$$u^+ = \int_0^{y^+} \frac{2}{b + [b^2 + 4\ a(y^+)]^{\frac{1}{2}}}\, dy^+ \qquad (17)$$

where $u^+ = u/u_\tau$, $y^+ = u_\tau y/\nu$, $b = 1$ and $a(y^+) = (\kappa y^+)^2\ [1 - \exp\ (-y^+/A^+)]^2$. Here A^+ is Van Driest's damping-length constant, equal to 26. Agreement between Equation 17 and computed profiles is excellent.

Whereas response to changes in energy supply is immediate in the inner region, the outer region of the boundary layer has a structure which is wake-like in nature and, as a result, the characteristic time scale of the flow is much larger than that of the inner region. Therefore, one would not expect this portion of the wall jet boundary layer to react instantaneously to the injection process at the wall but, over a period of time and after a substantial distance downstream, to adjust itself accordingly. This argument is readily supported by examining velocity-defect profiles of the type first illustrated by Clauser (1956). Figure 6 shows profiles at five stations downstream of an injection slot in zero pressure-gradient flow with no heat or mass transfer. The velocity-defect profile for the main-stream boundary layer, depicted by solid circles, follows the classic relationship identified by Clauser. However, a short distance downstream of the point of injection this relationship no longer holds since the friction velocity at the wall has quickly adjusted to the new conditions, whereas the outer region is still in a state of flux. Eventually, at some distance downstream of the slot, information regarding energy supply at the wall propagates throughout the entire boundary layer. As this happens the velocity-defect profiles approach the classic shape

once again.

The general features of mass and momentum transport, as calculated by the numerical method, appear to be correct judging from velocity profiles in each of the inner and outer layers. In order to verify the correctness of predictions about mass and heat transport, adiabatic wall temperature profiles downstream of an injection slot are plotted in Figure 7 for a variety of main-stream to secondary-stream velocity ratios and main-stream boundary layer dimensional variations. As before, all computations relate to flow development under zero pressure-gradient conditions. For the sake of comparison with other data results are plotted in the form suggested by Mukherjee (1976). The solid line in the figure is the mean adiabatic wall temperature distribution deduced from a variety of film-cooling data surveyed by the above researcher. The temperature distribution is expressed in terms of an efficiency, η, which is a function of non-dimensional distance, β. That is:

$$\eta = f(\beta)$$

where $\eta = \dfrac{T_1 - T_w}{T_1 - T_2}$ and

$$\beta = \left(\frac{\mu_2}{\mu_1}\,Re_2\right)^{-0.25}\frac{x}{d_1 m} \qquad (18)$$

with $Re_2 = \dfrac{\bar{u}_2 d_1}{\nu_2}$ and

$$m = \frac{\rho_2 u_2}{\rho_1 u_1} \; .$$

Here Re is a Reynolds number based on mean injection velocity and slot width. Subscripts 2, 1 and w refer to the cooling air, the hot gas and the wall, respectively.

The figure shows that in all cases the computer model predicts higher film-cooling efficiencies than Mukherjee's mean line. Discrepancies

between the two sources are smallest for both large values of β and small values of u_2/u_1. These observations suggest that heat transfer is not properly predicted in regions where a strong wall jet exists. To further support this conclusion, results of computations performed for weak wall jets in a three-slot film-cooling configuration are shown graphically in Figure 8. Note that diverging isotherms in the near-slot regions are discontinuous a few slot widths downstream of each point of injection. These mark the locations at which the local wall jet velocity maxima disappear and consequently at which the wall jet boundary layer is assumed to have degenerated into a conventional wall boundary layer. The corresponding changes in the eddy-viscosity profile apparently increase the rate of mixing as evidenced by more rapidly diverging isotherms after the switchover to a different mixing model.

Another factor that is partly responsible for underestimating mixing and therefore overestimating cooling protection is the omission of an eddy-viscosity term to account for vorticity due to a finite slot lip thickness. Pai and Whitelaw have shown that in the near-slot region the influence of slot lip thickness is significant. In fact, according to their data, for an increase in lip thickness w/d_1 from 0.13 to 0.38 (for a density ratio ρ_2/ρ_1 of unity), a decrease in cooling efficiency of some five percent was observed at a distance of ten slot widths downstream of the point of injection.

5. CONCLUSIONS AND RECOMMENDATIONS

It would appear that both the inner and outer regions of the boundary layer are properly modelled since the near-wall, law of the wall and outer wake-like layers behave as they should in incompressible, zero pressure-gradient flow with no heat or mass transfer. In cases with heat transfer the film-cooling efficiencies predicted by the model are higher in the near-slot region than those quoted by Mukherjee by an amount ranging from two percent for $u_2/u_1 = 0.2$ to approximately ten percent for $u_2/u_1 = 1.0$. These differences appear to be the result of:

i) underestimating turbulent mixing phenomena in that part of the mixing model used to evaluate eddy-viscosity when a local wall jet velocity maximum exists, and

ii) not accounting for increased mixing due to vorticity caused by a finite slot lip thickness.

It is recommended that future work attempt to verify the predictive capability of the model in flows with pressure gradients and that modifications be made to the mixing model in the near-slot region to improve agreement between model calculations and heat-transfer correlations.

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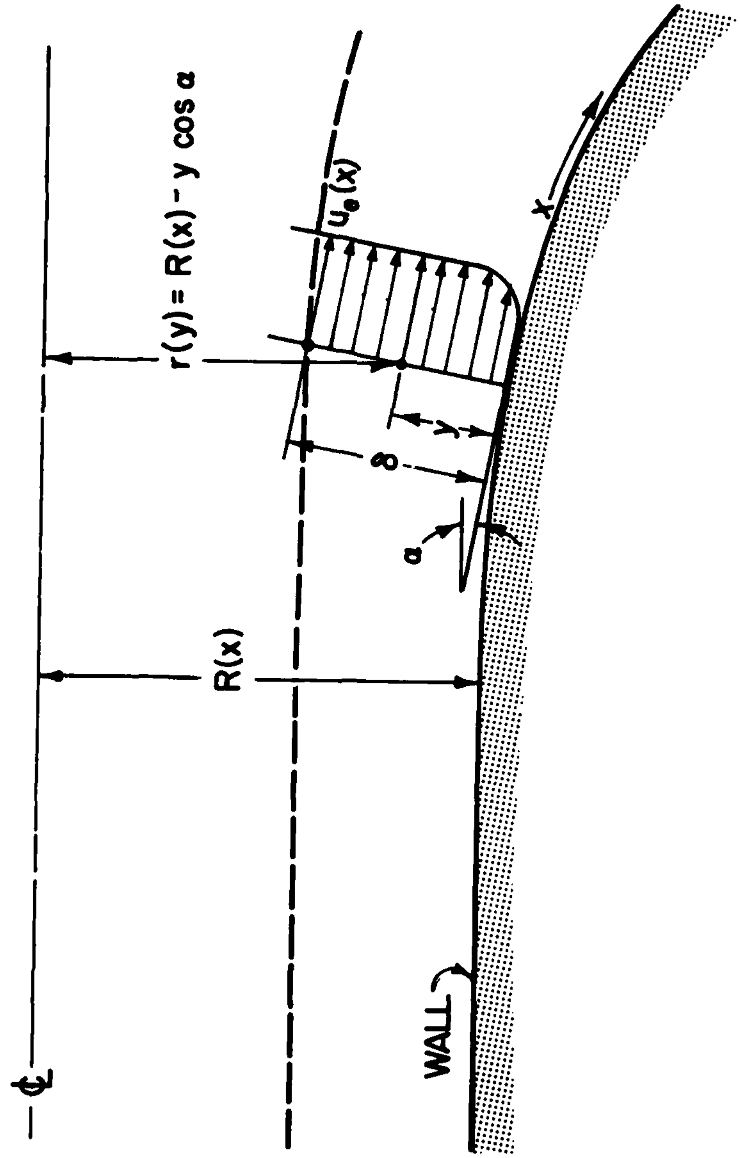


Figure 1: The Coordinate System for Boundary-Layer Calculations.

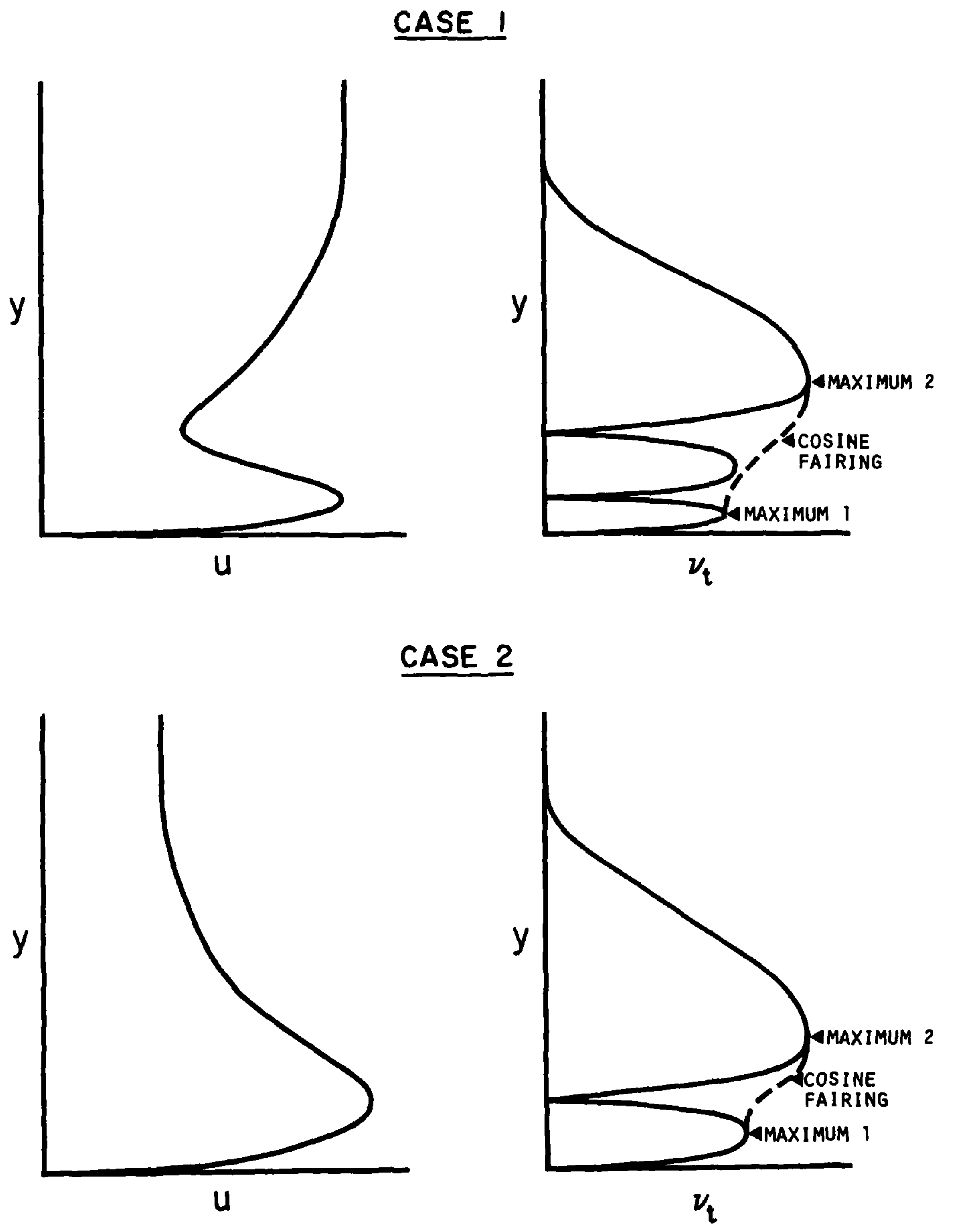


Figure 2: Wall Jet Boundary-Layer Velocity Profiles and Corresponding Eddy-Viscosity Profiles.

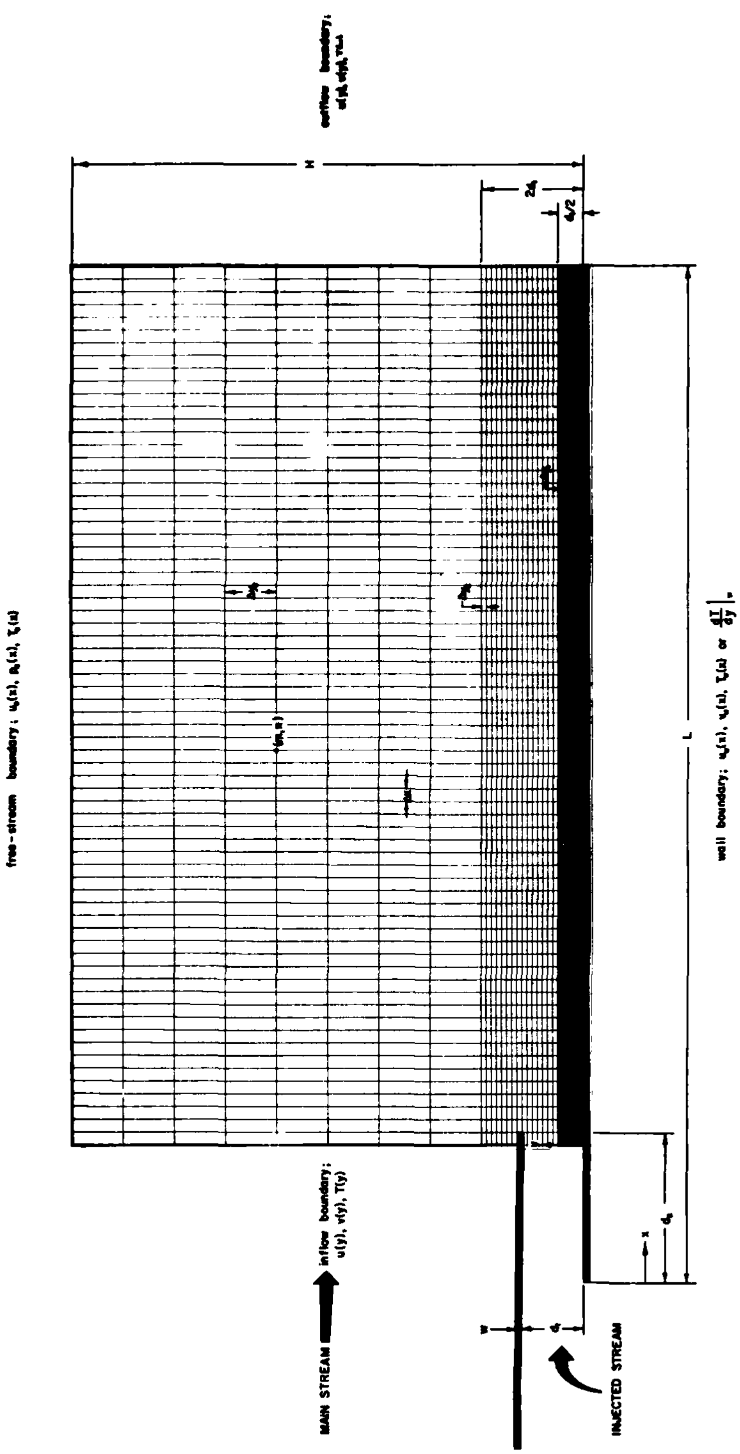


Figure 3: The Finite-Difference Grid Network.

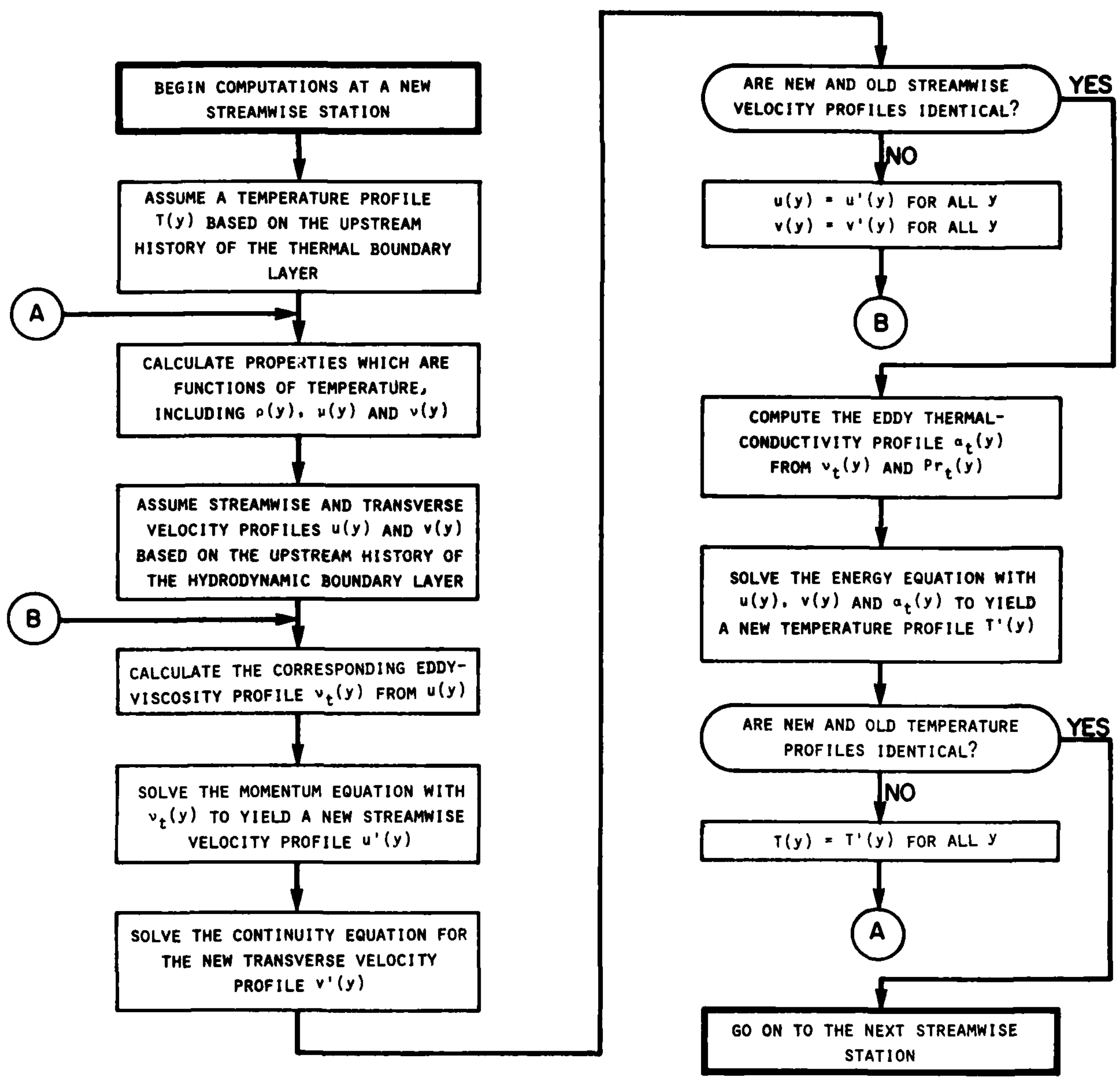


Figure 4: The Iterative Solution Procedure Used at Each Streamwise Station.

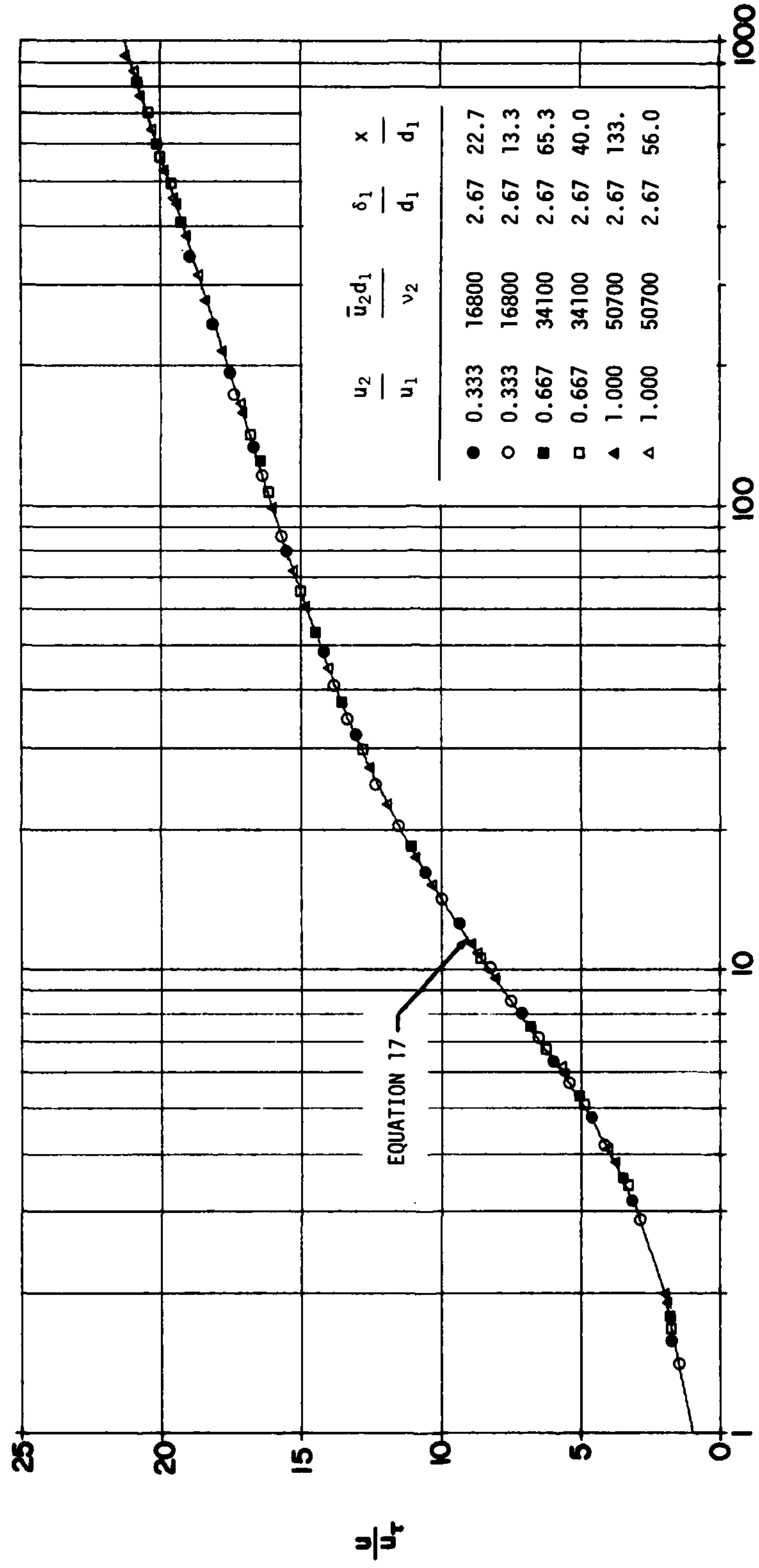


Figure 5: Velocity Profiles in the Near-Wall and Law of the Wall Regions.

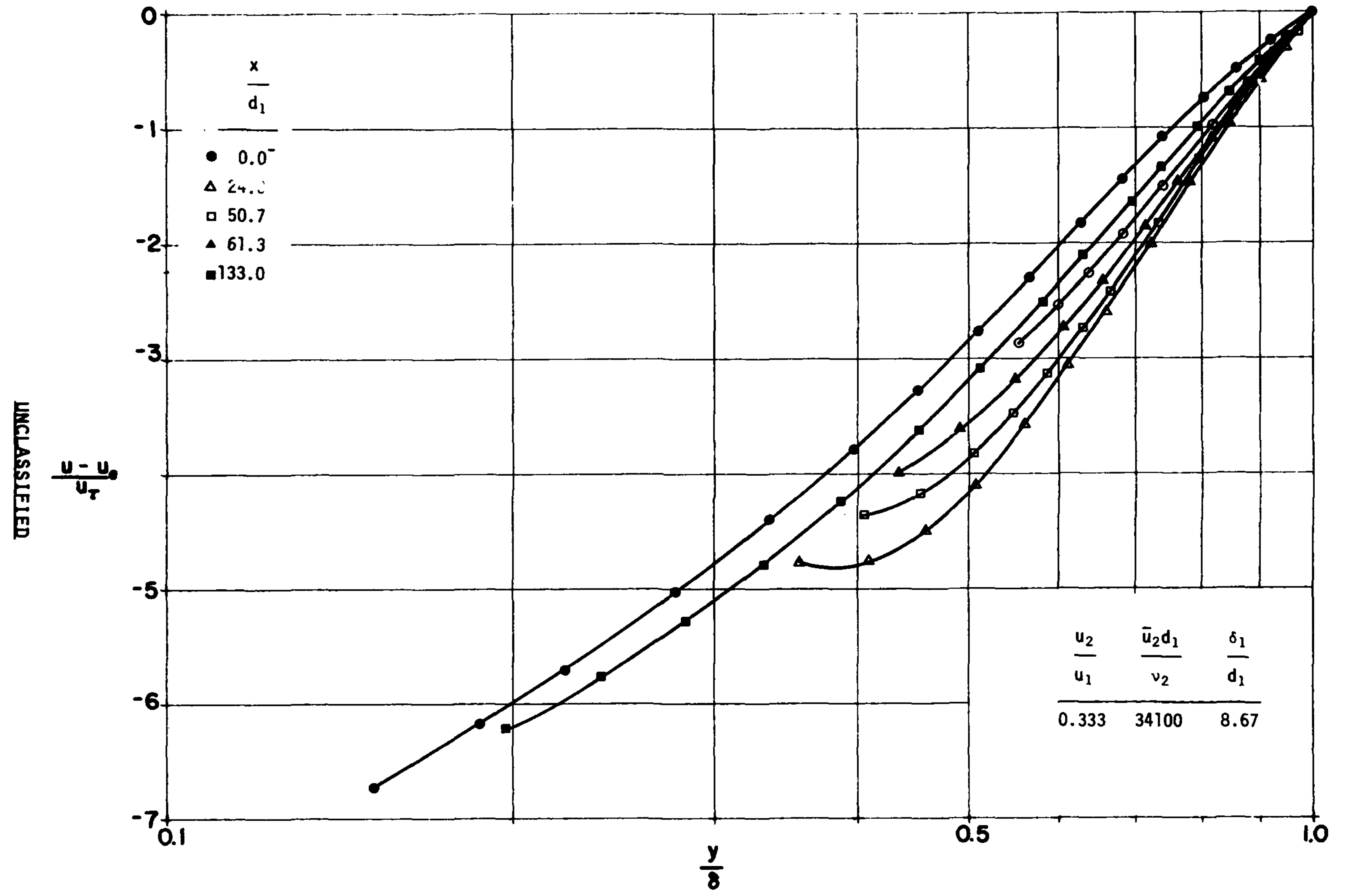


Figure 6: Velocity - Defect Profiles for the Developing Wall Jet Boundary Layer.

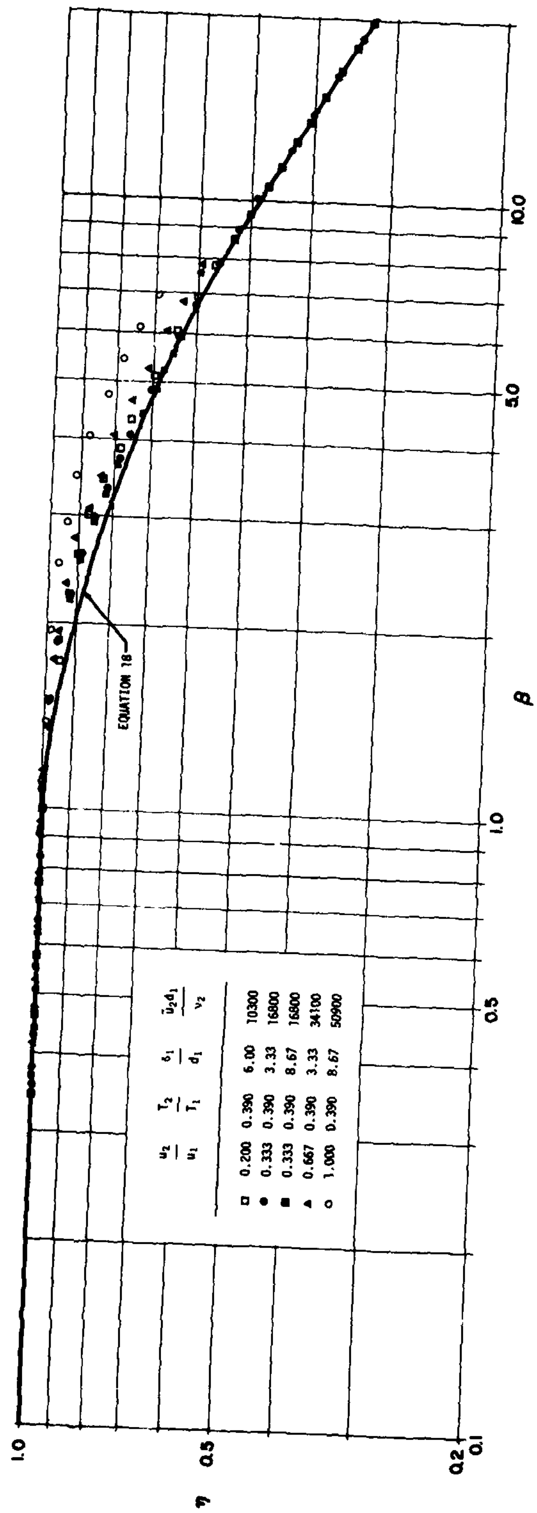


Figure 7: Adiabatic Wall Temperature Distributions.

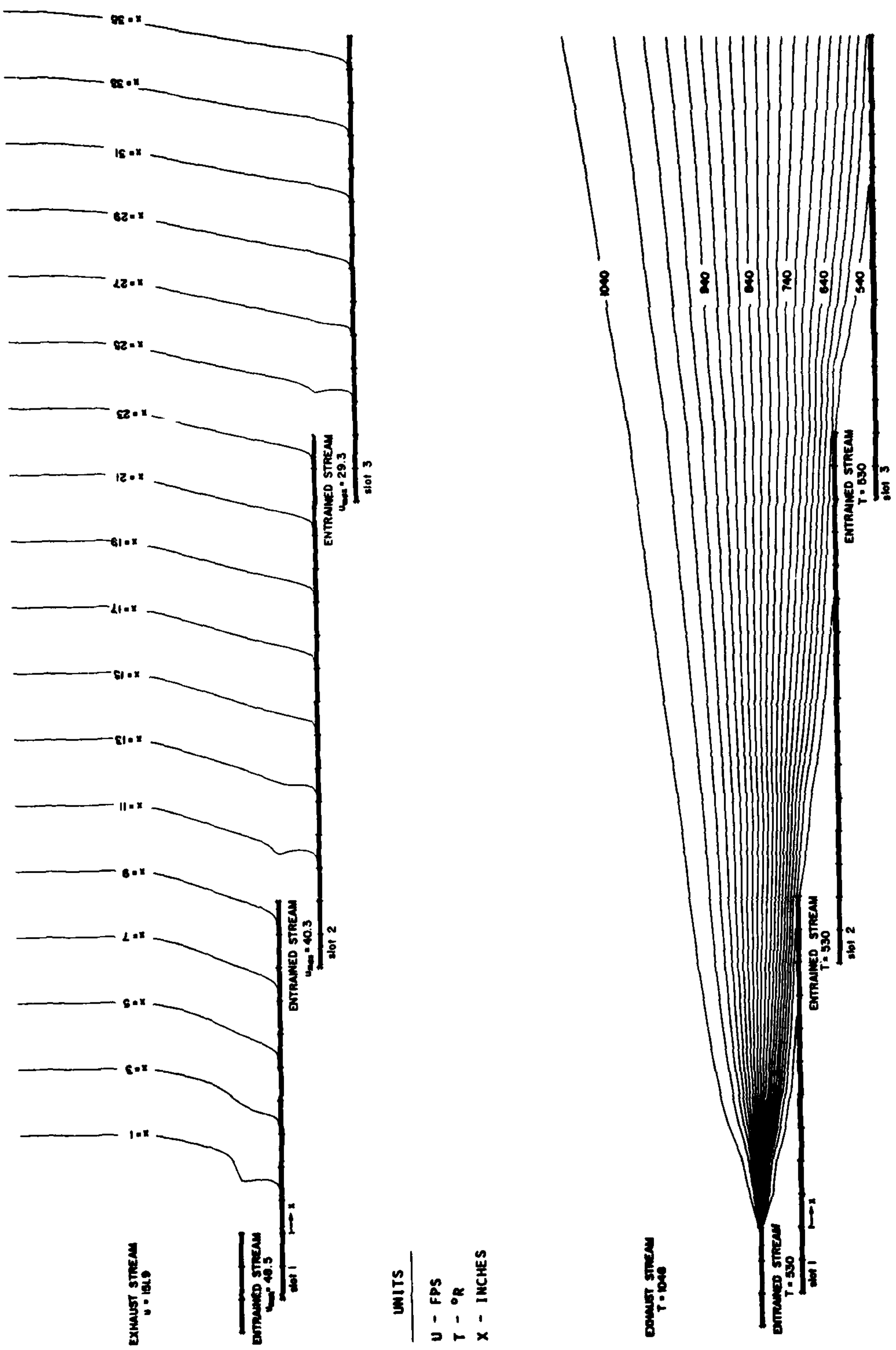


Figure 8: Velocity Profiles and Isotherms for a Three-Slot Film-Cooling Facility.

APPENDIX A

Description of Program FILM

APPENDIX A

Description of Program FILM

A detailed description of program FILM is presented in this appendix. Details are summarized under the following general headings;

i) Description of Key Programming Modules, and

ii) Description of Key Variables.

A documented program listing appears in Figure A-1.

Description of Key Programming Modules

Name	Type	Purpose
BLINT	sub	to integrate the boundary-layer velocity profile for the displacement thickness, momentum deficit thickness and velocity profile shape factor.
FILM	main	to syncronize the calling of major subroutines needed to initialize the boundary conditions, to compute the flow field and to store the computational results.
FLINK	sub	to read the outflow boundary conditions (from a disk file) from the last run to be executed and to construct the inflow boundary conditions for the present run, thereby linking the two flow fields.
FLMN1	sub	to read in general information about the coordinate system, grid network, ambient conditions, fluid dynamics and other phenomena that are characteristic of the run.
FLMN2	sub	to read in information about and to set up the streamwise boundary conditions including duct radius, duct wall slope, bleed velocity at the wall, free-stream temperature, static pressure and free-stream velocity.
FLMN3	sub	to read in information about and to set up the inflow boundary conditions including transverse grid step size and position, temperature, density and streamwise velocity.
FLMTD	sub	to calculate the distributions of eddy thermal conductivity and temperature throughout the boundary layer at a particular streamwise station.

Name	Type	Purpose
FLMVU	sub	to calculate the distributions of eddy viscosity, streamwise velocity and transverse velocity throughout the boundary layer at a particular streamwise station.
FMRCH	sub	to coordinate the downstream-marching procedure by calling subroutines to solve the differential equations for the conservation of mass, momentum and energy. FMRCH monitors convergence parameters and steps the solution from one streamwise station to the next.
FTIDY	sub	to store the outflow boundary conditions from a given run in a disk file for future reference.
GNINT	func	to fit a third-order polynomial to four data points and to return the value of the function for some specified point within the range over which the polynomial fit was evaluated.
MEW	func	to evaluate the dynamic viscosity of air as a function of temperature by interpolating in a table of temperatures and corresponding viscosities.
OTPT1	sub	to print out on the line printer the streamwise distribution of some quantity which is stored in the form of an array.
OTPT2	sub	to print out on the line printer the transverse distribution of some quantity which is stored in the form of an array.
QADD	sub	to allow the user to include any additional heat transfer terms in the heat balance at the duct wall.
THCON	func	to evaluate the thermal conductivity of air as a function of temperature by interpolating in a table of temperatures and corresponding thermal conductivities.
TRIDI	sub	to solve a tridiagonally-banded system of linear algebraic equations.
WLAW	sub	to solve for u_τ in the law of the wall expression, given distance from the wall, y, and corresponding streamwise velocity, u. A Newton-Raphson root-finding technique is employed.

Description of Key Variables

Fortran Variable Name	Conventional Symbol	Description
A	$A_{m,n}$	is an array which contains the A coefficients in the system of algebraic equations used to solve the differential equations.
AA	A^{+}	is Van Driest's damping-length parameter (equal to 26).
ALM	$\alpha_{m,n}$	is an array which contains the transverse distribution of thermal conductivity at streamwise station m.
ALPHA	$\alpha(x)$	is an array which contains the streamwise distribution of duct wall slope measured from the duct centre line (required for axisymmetric flow only).
ALPHU		is the slope of the duct wall, measured from the duct centre line, one station upstream of the point of injection (required for axisymmetric flow only).
AP		is a working array.
AQ		is a working array.
ATRB	$\alpha_{t_{m,n}}$	is an array which contains the transverse distribution of eddy thermal conductivity at streamwise station m.
AU		is a working array.
B	$B_{m,n}$	is an array which contains the B coefficients in the system of algebraic equations used to solve the differential equations.
C	$C_{m,n}$	is an array which contains the C coefficients in the system of algebraic equations used to solve the differential equations.
CF	c_f	is the skin friction coefficient.
COORD		is a flag that specifies the coordinate system. COORD positive implies flow over a body of revolution. Otherwise, plane flow is assumed.
D	$D_{m,n}$	is an array which contains the D coefficients in the system of algebraic equations used to solve the differential equations.

Fortran Variable Name	Conventional Symbol	Description
DDWIN		is the sum of DWIN and D1.
DISP	δ^*	is the displacement thickness of the boundary layer.
DPDX	$\frac{dp}{dx}$	is the streamwise gradient of static pressure.
DTDX	$\frac{dT}{dx}$	is the streamwise linear gradient of temperature.
DUDYi	$\frac{du}{dy}$	is the transverse gradient of streamwise velocity for any character i. The gradient at the wall is denoted by $i = W$. A maximum gradient is denoted by $i = M$.
DUEDX	$\frac{du}{dx}$	is the streamwise linear gradient of free-stream velocity.
DVDX	$\frac{dv}{dx}$	is the streamwise linear gradient of transverse velocity.
DW		is the duct wall thickness.
DWALL		is the additive constant in the law of the wall expression used to create the inflow velocity profiles. It has a value of 5.24 in this study.
DWIN	w	is the slot lip thickness.
DX	Δx	is the grid step size in the x-direction.
DY	Δy_n	is an array which contains the transverse distribution of grid step size in the y-direction at all streamwise stations.
DYY	Δy_1	is the grid step size in the y-direction of the finest grid zone.
D1	d_1	is the injection slot width.
D2	d_2	is the length of the injection slot.
DELT1	δ_1	is the thickness of the main-stream boundary layer (just upstream of the point of injection) or the wall jet boundary layer.
DELT2	δ_2	is the thickness of the slot boundary layer or the distance from the wall to the point of wall jet maximum velocity.

Fortran Variable Name	Conventional Symbol	Description
FNRMT		is the fractional displacement norm of the temperature profile. It is used to monitor convergence of the profile.
FNRMU		is the fractional displacement norm of the velocity profile. It is used to monitor convergence of the profile.
GC	g_c	is a constant (equal to 32.2 lb_m-ft/lb_f-sec^2).
H	H	is the velocity profile shape factor.
IFi		is a disk file number for $1 \le i \le 10$.
IRECT		is a record pointer for the disk file retaining transverse temperature profiles.
IRECU		is a record pointer for the disk file retaining transverse profiles of streamwise velocity.
JDAT		is a flag used in setting up the inflow streamwise velocity profile.
JHEAT		is a flag that specifies whether or not heat transfer is to be included. JHEAT = 0 implies that the energy equation will not be solved and that the temperature distribution specified as inflow boundary conditions will exist throughout the flow field. Otherwise, the energy equation will be solved.
JOUT		is the transverse station number corresponding to the location of YOUT.
JPAR		is a flag used in setting up the streamwise distributions of static pressure and free-stream velocity.
JPRES		is a flag used in setting up the streamwise distribution of static pressure.
JPRN		is a flag that indicates whether or not results of the computations will be printed out. JPRN = 0 implies no line-printer output. Otherwise, output will result.
JRADL		is a flag used in setting up the streamwise distributions of duct radius and duct wall slope.

Fortran Variable Name	Conventional Symbol	Description
JSEP		is a flag used in setting up the streamwise distributions of static pressure and free-stream velocity.
JSLOT		is the slot number which identifies the flow field being computed presently.
JSTOT		is the total number of slots in the structure being analyzed.
JSTRT		is a flag that indicates where data regarding the main stream is to be acquired. JSTRT = 0 implies that such data will be supplied by the user as input. Otherwise, the outflow boundary conditions from the last run to be executed will be fetched from disk files and used as input conditions for the present run.
JT		is a flag used in setting up the inflow temperature profile.
JTOP		is the transverse station number corresponding to the location of YTOP.
JU		is a flag used in setting up the streamwise distribution of free-stream velocity.
JV		is a flag used in setting up the inflow transverse velocity profile.
JVEL		is a flag used in setting up the inflow streamwise and transverse velocity profiles.
JDEL1		is the transverse station number corresponding to the thickness DELT1.
JDEL2		is the transverse station number corresponding to the thickness DELT2.
KDGEN		is a flag indicating whether or not the wall jet boundary layer has degenerated to a conventional turbulent wall boundary layer.
KOUNT	m	is the streamwise station number.
M	M	is the number of stations in the streamwise direction at which computations are performed.
MEWAL	μ_w	is the fluid dynamic viscosity at the wall.

Fortran Variable Name	Conventional Symbol	Description
MOM	θ	is the momentum deficit thickness of the boundary layer.
N	N	is the number of stations in the transverse direction at which computations are performed.
NC		is a four-element array that usually contains station numbers corresponding to the wall, any grid-grid interface and the edge of the boundary layer.
NDIM		is the number of real elements in a file record (1000 in this program).
NEW	ν	is the local fluid kinematic viscosity.
NOLD		is N for the last run to be executed.
N1		is the transverse station number that corresponds to distance d_1 from the wall.
N2		is the transverse station number that corresponds to distance $(d_1 + w)$ from the wall.
NC1		is the transverse station number at the interface between fine (grid zone 1) and medium (grid zone 2) grids.
NC2		is the transverse station number at the interface between medium (grid zone 2) and coarse (grid zone 3) grids.
PATM	P_a	is the ambient pressure outside the duct. This pressure may be required for computing heat transfer from the duct to the surroundings in subroutine QADD.
PI	π	is a constant (equal to 3.1415926).
PMAIN		is the static pressure in the duct one station upstream of the point of injection.
PPLUS	p^+	is the dimensionless pressure-gradient parameter for use in modifying Van Driest's near-wall mixing-length expression.
PR	p_m	is the static pressure at streamwise station m.
PRES	$p(x)$	is an array which contains the streamwise distribution of static pressure.

Fortran Variable Name	Conventional Symbol	Description
PRLAM	Pr	is the fluid molecular Prandtl number.
PRTi		is a term used in modifying the near-wall mixing-length expression. i ranges from 1 to 3.
PRTRB	Pr_t	is the fluid turbulent Prandtl number.
PSLOT		is the static pressure in the injection slot one station upstream of the point of injection.
PARM1	Π_1	is Coles' profile parameter for the main-stream boundary layer (just upstream of the point of injection).
PARM2	Π_2	is Coles' profile parameter for the slot boundary layers.
PART2		is an array which contains the transverse distribution of the quantity $$\frac{r^k_{m,n+1} - r^k_{m,n-1}}{r^k_{m,n}} .$$
PART3		is an array which contains the transverse distribution of the quantity $$\frac{\rho_{m,n+1} - \rho_{m,n-1}}{\rho_{m,n}} .$$
PART4		is an array which contains the transverse distribution of the quantity $$\frac{2\Delta y^2_{m,n}}{\Delta x} .$$
PART5		is an array which contains the transverse distribution of the quantity $$\frac{2\Delta y^2_{m,n}\ (u_{m-2,n} - 4u_{m-1,n})}{\Delta x} .$$
PART6		is an array which contains the transverse distribution of the quantity $$\frac{2g_c\Delta y^2_{m,n}\ (3p_m - 4p_{m-1} + p_{m-2})}{\Delta x} .$$

Fortran Variable Name	Conventional Symbol	Description
PART7		is an array which contains the transverse distribution of the quantity $\dfrac{2\Delta y^2_{m,n}\,(T_{m-2,n} - 4T_{m-1,n})}{\Delta x}$.
PM1	p_{m-1}	is the static pressure at streamwise station m-1.
PM2	p_{m-2}	is the static pressure at streamwise station m-2.
QWALL	q_{w_m}	is the net heat transfer from the duct wall at a given streamwise station.
RAD	R_m	is the duct radius at streamwise station m (used for axisymmetric flow only).
RADUP		is the duct radius one station upstream of the point of injection (required for axisymmetric flow only).
RDIUS	$R(x)$	is an array which contains the streamwise distribution of duct radius (required for axisymmetric flow only).
RGAS	R	is the gas constant for use in the equation of state for both streams.
RLOC	$r_{m,n}$	is an array which contains the transverse distribution of local radius at streamwise station m (required for axisymmetric flow only).
RO	$\rho_{m,n}$	is an array which contains the transverse distribution of density at streamwise station m.
ROEE	ρ_e	is the density at the edge of the boundary layer.
ROEUE	$\rho_e u_e$	is the product of density and streamwise velocity at the edge of the boundary layer.
ROWAL	ρ_w	is the fluid density at the wall.
RAD1	R_{m-1}	is the duct radius at streamwise station m-1 (required for axisymmetric flow only).
RAD2	R_{m-2}	is the duct radius at streamwise station m-2 (required for axisymmetric flow only).
RLOC1	$r_{m-1,n}$	is an array which contains the transverse distribution of local radius at streamwise station m-1 (required for axisymmetric flow only).

Fortran Variable Name	Conventional Symbol	Description
RLOC2	$r_{m-2,n}$	is an array which contains the transverse distribution of local radius at streamwise station m-2 (required for axisymmetric flow only).
RO1	$\rho_{m-1,n}$	is an array which contains the transverse distribution of density at streamwise station m-1.
RO2	$\rho_{m-2,n}$	is an array which contains the transverse distribution of density at streamwise station m-2.
SCRAP		is a working array.
TATM	T_a	is the ambient temperature outside the duct. This temperature may be required for computing heat transfer from the duct to the surroundings in subroutine QADD.
TFREE	T_{e_m}	is the temperature in the core of the main stream at station m.
TINF	$T_e(x)$	is an array which contains the streamwise distribution of free-stream temperature.
TM	$T_{m,n}$	is an array which contains the transverse distribution of temperature at streamwise station m.
TMLAS	$T'_{m,n}$	is an array which contains the transverse distribution of temperature at streamwise station m from the last iteration in the solution of the energy equation.
TMOLD	$T'_{m,n}$	is an array which contains the transverse distribution of temperature at streamwise station m from the last iteration. The iteration in question is one necessitated when heat transfer from the wall is a function of the unknown wall temperature.
TNLIM		is the value that the temperature-profile fractional displacement norm must assume before convergence is sufficient.
TWMAX	$T_{w_{max}}$	is the maximum temperature that the wall can assume. If at any time during the run the wall temperature should exceed this value the job is automatically terminated in a controlled manner.
TINF1		is the uniform temperature of the main stream.
TINF2		is the uniform temperature of the injected stream.

Fortran Variable Name	Conventional Symbol	Description
TM1	$T_{m-1,n}$	is an array which contains the transverse distribution of temperature at streamwise station m-1.
TM2	$T_{m-2,n}$	is an array which contains the transverse distribution of temperature at streamwise station m-2.
UEE	u_e	is the streamwise velocity at the edge of the boundary layer.
UFREE	u_{e_m}	is the streamwise velocity in the core of the main stream at station m.
UINF	$u_e(x)$	is an array which contains the streamwise distribution of free-stream velocity.
UM	$u_{m,n}$	is an array which contains the transverse distribution of streamwise velocity at streamwise station m.
UMLAS	$u'_{m,n}$	is an array which contains the transverse distribution of streamwise velocity at streamwise station m from the last iteration in the solution of the momentum equation.
UNLIM		is the value that the velocity-profile fractional displacement norm must assume before convergence is sufficient.
UTAU	u_τ	is the friction or shear velocity.
UDEL1	u_1	is the streamwise velocity at the edge of the main-stream boundary layer.
UDEL2	u_2	is the wall jet maximum streamwise velocity or the streamwise velocity at the edge of the slot boundary layer.
UM1	$u_{m-1,n}$	is an array which contains the transverse distribution of streamwise velocity at streamwise station m-1.
UM2	$u_{m-2,n}$	is an array which contains the transverse distribution of streamwise velocity at streamwise station m-2.
VM	$v_{m,n}$	is an array which contains the transverse distribution of transverse velocity at streamwise station m.
VSC	$\nu_{m,n}$	is an array which contains the transverse distribution of kinematic viscosity at streamwise station m.
VTMJ	$\nu_{t_{max_1}}$	is the eddy-viscosity maximum in the jet region of the wall jet boundary layer.

Fortran Variable Name	Conventional Symbol	Description
VTMM	$\nu_{t_{max_2}}$	is the eddy-viscosity maximum in the outer region of the wall jet boundary layer.
VTRB	$\nu_{t_{m,n}}$	is an array which contains the transverse distributions of eddy viscosity at streamwise station m.
VWAL	v_{w_m}	is the bleed velocity at the wall at streamwise station m.
VWALL	$v_w(x)$	is an array which contains the streamwise distribution of bleed velocity at the wall.
VWPLS	v_w^+	is the dimensionless mass-transfer parameter for use in modifying Van Driest's near-wall mixing-length expression.
VM1	$v_{m-1,n}$	is an array which contains the transverse distribution of transverse velocity at streamwise station m-1.
VM2	$v_{m-2,n}$	is an array which contains the transverse distribution of transverse velocity at streamwise station m-2.
X	x	is the streamwise coordinate.
XH	H	is the height of the grid network, measured from the duct wall.
XK	κ	is von Karman's mixing-length constant (equal to 0.435).
XL	L	is the distance from the entrance of the injection slot to the downstream end of the grid network.
XLAMB	λ	is a proportionality constant, equal to 0.09, relating the mixing length and boundary-layer thickness.
XMASS	m_2	is the mass of fluid exiting the injection slot.
XOLD		is an array which contains the transverse distribution of some quantity at the outflow boundary of the last flow field to be computed.
Y	y_n	is an array which contains the transverse distribution of distance from the wall at all streamwise stations.
YMIX	ℓ	is the mixing length.
YOLD		is an array which contains the transverse distribution of distance from the wall at the outflow boundary of the last flow field to be computed.

Fortran Variable Name	Conventional Symbol	Description
YOUT	$\frac{\delta\lambda}{\kappa}$	is the point at which the inner and outer portions of the boundary layer intersect.
YTOP		is the transverse location of local maximum eddy viscosity VTMM.

```
//FILM JOB (0162,101911,ME02),'MURRAY',NOTIFY=L357421,
// MSGLEVEL=(1,1),CLASS=L,TIME=(1,0)
//*MAIN LINES=20,ORG=RM028
// EXEC FORTXCLG,PARM.FORT='AUTODBL(DBL4),ALC,OPTIMIZE(2)'
//SYSTERM DD SYSOUT=A
//FORT.SYSIN DD *

C******************************** FILM *********************************
C******************************** FILM *********************************
C******************************** FILM *********************************
C
C
C     THE PURPOSE OF THIS PROGRAM IS TO CALCULATE THE DEVELOPMENT OF
C     INCOMPRESSIBLE TURBULENT WALL JET BOUNDARY LAYERS IN MULTIPLY-
C     SLOTTED FILM-COOLING APPLICATIONS. THIS IS ACCOMPLISHED BY SOLVING
C     THE DIFFERENTIAL EQUATIONS FOR THE CONSERVATION OF MASS, MOMENTUM
C     AND ENERGY USING A DOWNSTREAM-MARCHING, IMPLICIT, ITERATIVE,
C     FINITE-DIFFERENCE METHOD. THE TURBULENT TRANSPORT OF MOMENTUM
C     AND HEAT IS MODELLED BY THE BOUSSINESQ DIFFUSIVITY CONCEPT AND
C     PRANDTL MIXING-LENGTH HYPOTHESIS.
C
C     THE MAIN-LINE ROUTINE FUNCTIONS SIMPLY TO CALL MAJOR SUBROUTINES
C     WHICH ARE VITAL TO THE SOLUTION PROCEDURE.
C
C
      INTEGER COORD
      DIMENSION RDIUS(150),ALPHA(150),UINF(150),TINF(150),PRES(150),
     1 SCRAP(150),VWALL(150),
     2 UM(1000),UM1(1000),UM2(1000),VM(1000),VM1(1000),VM2(1000),
     3 TM(1000),TM1(1000),TM2(1000),RO(1000),RO1(1000),RO2(1000),
     4 Y(1000),DY(1000),NC(4),TMLAS(1000),UMLAS(1000),VSC(1000),
     5 VTRB(1000),RLOC(1000),RLOC1(1000),RLOC2(1000),XOLD(1000),
     6 PART2(1000),PART3(1000),PART4(1000),PART5(1000),PART6(1000),
     7 A(1000),B(1000),C(1000),D(1000),AP(1000),AQ(1000),AU(1000),
     8 PART7(1000),ALM(1000),ATRB(1000),TMOLD(1000),YOLD(1000)
      EQUIVALENCE (XOLD(1),ALM(1)),(YOLD(1),ATRB(1)),(VSC(1),SCRAP(1))
      COMMON IN,IOT,IF1,IF2,IF3,IF4,IF5,IF6,IF7,IF8,IF9,IF10,IRECU,IRECT
      DEFINE FILE 11(50,8000,L,IRECU)
      DEFINE FILE 12(50,8000,L,IRECT)
      DEFINE FILE 13(1,8000,L,IB)
      DEFINE FILE 14(1,8000,L,IB)
      DEFINE FILE 15(1,8000,L,IB)
      DEFINE FILE 16(1,8000,L,IB)
      DEFINE FILE 17(1,8000,L,IB)
      DEFINE FILE 18(1,8000,L,IB)
      DEFINE FILE 19(1,8000,L,IB)
      DEFINE FILE 20(100,8,L,IB)
C
C
C     I/O DEVICE NUMBERS, FILE NUMBERS AND RECORD POINTERS ARE
C     INITIALIZED BELOW.
C
      IN=5
      IOT=6
      IRECU=1
      IRECT=1
      NDIM=1000
      IF1=11
      IF2=12
      IF3=13
      IF4=14
      IF5=15
      IF6=16
      IF7=17
      IF8=18
      IF9=19
      IF10=20
C
C
C     SUBROUTINE FLMN1 IS CALLED TO READ IN GENERAL INFORMATION ABOUT
C     THE GRID NETWORK, AMBIENT CONDITIONS AND VARIOUS PHENOMENA THAT
C     ARE PECULIAR TO A PARTICULAR RUN.
C
      CALL FLMN1 (JPRN,JSTRT,JHEAT,TWMAX,M,D1,D2,DX,DYY,XL,XM,PATM,
     1 TATM,XK,AA,DWALL,RGAS,GC,DW,DWIN,COORD)
C
C
C     SUBROUTINE FLMN2 IS CALLED TO READ IN INFORMATION ABOUT AND TO
C     SET UP THE WALL AND FREE-STREAM BOUNDARY CONDITIONS.
C
      CALL FLMN2 (JPRN,COORD,M,D2,DX,ALPHU,RADUP,RDIUS,ALPHA,UINF,
     1 TINF,VWALL,PRES,SCRAP,GC,RGAS,PSLOT,PMAIN)
C
C
C     SUBROUTINE FLMN3 IS CALLED TO READ IN INFORMATION ABOUT AND TO
C     SET UP THE INFLOW BOUNDARY CONDITIONS.
C
      CALL FLMN3 (D1,DYY,DWIN,DWALL,XK,RGAS,M,XM,AA,Y,DY,JSTRT,JPRN,
     1 COORD,RAD1,RAD2,PSLOT,PMAIN,UM,UM1,UM2,VM,VM1,VM2,TM,TM1,TM2,
     2 RO,RO1,RO2,RDIUS,ALPHA,PRES,N1,N2,N,NC1,NC2,NC,NDIM,XOLD,YOLD,
     3 RLOC,RLOC1,RLOC2,RADUP,ALPHU)
C
C
C     SUBROUTINE FMRCH IS CALLED TO CARRY OUT THE DOWNSTREAM-MARCHING
C     SOLUTION PROCEDURE.
C
      CALL FMRCH (UM,UM1,UM2,VM,VM1,VM2,RO,RO1,RO2,TM,TM1,TM2,Y,DY,JPRN,
     1 M,D1,D2,DX,XL,XM,PATM,TATM,XK,AA,RGAS,GC,DW,DWIN,COORD,RAD1,RAD2,
     2 ALPHA,RDIUS,UINF,TINF,VWALL,PRES,PSLOT,PMAIN,N1,N2,N,NC1,NC2,
     3 UMLAS,TMLAS,VSC,VTRB,RLOC,RLOC1,RLOC2,PART2,PART3,PART4,PART5,
     4 PART6,A,B,C,D,AP,AQ,AU,PART7,ALM,ATRB,TMOLD,JHEAT,TWMAX,NDIM)
C
C
C     SUBROUTINE FTIDY IS CALLED TO STORE THE OUTFLOW BOUNDARY COND-
C     ITIONS AFTER THE FLOW FIELD HAS BEEN COMPUTED.
C
      CALL FTIDY (UM,UM1,TM,TM1,VM,VM1,Y,NDIM,N)
C
C
      STOP
      END

C******************************** FLMN1 ********************************
C******************************** FLMN1 ********************************
C******************************** FLMN1 ********************************
C
C
      SUBROUTINE FLMN1 (JPRN,JSTRT,JHEAT,TWMAX,M,D1,D2,DX,DYY,XL,XM,
     1 PATM,TATM,XK,AA,DWALL,RGAS,GC,DW,DWIN,COORD)
C
C
C     THE PURPOSE OF THIS SUBROUTINE IS TO READ IN GENERAL INFORMATION
C     ABOUT THE COORDINATE SYSTEM, GRID NETWORK, AMBIENT CONDITIONS,
C     FLUID DYNAMIC AND VARIOUS OTHER PHENOMENA THAT ARE TYPICAL OF A
C     PARTICULAR RUN.
C
C
      INTEGER COORD
      COMMON IN,IOT,IF1,IF2,IF3,IF4,IF5,IF6,IF7,IF8,IF9,IF10,IRECU,IRECT
C
C
C     SOME PARAMETERS ARE ASSIGNED VALUES.
C
      GC=32.2
      XK=0.435
      AA=26.0
      DWALL=5.24
C
C
C     AND SOME PARAMETERS ARE READ IN BELOW.
C
      READ(IN,10)JPRN,COORD,JSTRT,JSLOT,JSTOT,JHEAT
   10 FORMAT(10I2)
      READ(IN,20)D1,D2,DX,DYY,XL,XM,DW,DWIN
   20 FORMAT(8F10.6)
      READ(IN,25)PATM,TATM,RGAS,TWMAX
   25 FORMAT(8F12.6)
      M=1.0001*((XL-D2)/DX+1.0)
C
C
C     THIS INFORMATION IS PRINTED OUT BELOW, IF THIS OPTION HAS BEEN
C     SPECIFIED BY THE USER.
C
      IF(JPRN)30,210,30
   30 WRITE(IOT,40)
   40 FORMAT(42X,'FILM COOLING INITIALIZATION SUMMARY'///5X,
     1 '1) GENERAL INFORMATION ')
      WRITE(IOT,50)JSLOT,JSTOT
   50 FORMAT(/10X, '-CONFIGURATION:  SLOT NUMBER',I3,' OF A',I3,
     1 ' SLOT FACILITY')
      IF(COORD)60,60,80
   60 WRITE(IOT,70)
   70 FORMAT(/10X,'-COORDINATE SYSTEM:  PLANE')
      GO TO 100
   80 WRITE(IOT,90)
   90 FORMAT(/10X,'-COORDINATE SYSTEM:  AXISYMMETRIC')
  100 WRITE(IOT,110)
  110 FORMAT(//5X, '2) GRID GEOMETRY INFORMATION ')
      WRITE(IOT,120)D1,D2,D2,XL,XM,DX
  120 FORMAT(/10X,'-SLOT HEIGHT:  ',F6.2,' INCHES'//10X,
     1 '-SLOT ENTRY LENGTH:  ', F6.2,' INCHES'//10X,
     2 '-LONGITUDINAL CALCULATION INTERVAL:  FROM X =',F6.2,
     3 ' INCHES TO X =',F6.2,' INCHES'//10X,'-TRANSVERSE CALCULATION ',
     4 'INTERVAL:  FROM Y = 0.00 INCHES TO Y ='  ,F6.2,' INCHES'//10X,
     5 '-LONGITUDINAL STEP SIZE:  ',F7.5,' INCHES')
      IF(COORD)130,130,150
  130 WRITE(IOT,140)DYY
  140 FORMAT(/10X,'-FINEST TRANSVERSE STEP SIZE:  ', F8.6,' INCHES')
      GO TO 170
  150 WRITE(IOT,160)DYY
  160 FORMAT(/10X,'-FINEST RADIAL STEP SIZE:  ', F8.6,' INCHES')
  170 WRITE(IOT,180)DWIN,DW
  180 FORMAT(/10X,'-INNER WALL THICKNESS:  ', F6.4,' INCHES'//10X,
     1 '-OUTER WALL THICKNESS:  ',F6.4,' INCHES')
      WRITE(IOT,190)PATM,TATM
  190 FORMAT(//5X,'3) ATMOSPHERIC INFORMATION '//10X,'-AMBIENT ',
     1 'PRESSURE:  ',F8.4,' PSIA'//10X, '-AMBIENT TEMPERATURE:  ',
     2 F8.3,' ''R')
      WRITE(IOT,200)XK,DWALL,AA,RGAS
  200 FORMAT(// 5X,'4) FLUID DYNAMIC INFORMATION '//10X,
     1 '-VON KARMAN''S LAW OF THE WALL CONSTANT:  ',F6.4//10X,
     2 '-ADDITIVE CONSTANT IN LAW OF THE WALL:  ',F6.3//10X,
     3 '-VAN DRIEST''S DAMPING PARAMETER:  ',F6.2//10X,
     4 '-FLUID GAS CONSTANT:  ',F7.3,' FT-LBF/LBM-R')
C
C
C     UNITS OF SOME PARAMETERS ARE ALTERED BELOW FOR CONSISTENCY.
C
  210 DX=DX/12.
      DYY=DYY/12.
      D1=D1/12.
      D2=D2/12.
      XM=XM/12.
      XL=XL/12.
      DW=DW/12.
      DWIN=DWIN/12.
      PATM=PATM*144.
C
C
      RETURN
      END

C******************************** FLMN2 ********************************
C******************************** FLMN2 ********************************
C******************************** FLMN2 ********************************
C
C
      SUBROUTINE FLMN2 (JPRN,COORD,M,D2,DX,ALPHU,RADUP,RDIUS,ALPHA,UINF,
     1 TINF,VWALL,PRES,SCRAP,GC,RGAS,PSLOT,PMAIN)
C
C
C     THE PURPOSE OF THIS SUBROUTINE IS TO READ IN INFORMATION ABOUT
C     AND TO SET UP THE STREAMWISE BOUNDARY CONDITIONS, INCLUDING
C
C          1) DUCT RADIUS,
C
C          2) DUCT WALL SLOPE,
C
```

Figure A-1: A Documented Listing for Program Film (Page 1).

```
C          3) BLEED VELOCITY AT THE WALL.
C
C          4) FREE-STREAM TEMPERATURE, AND
C
C          5) STATIC PRESSURE AND FREE-STREAM VELOCITY.
C
C
      INTEGER COORD
      DIMENSION RDIUS(1),ALPHA(1),VWALL(1),UINF(1),PRES(1),TINF(1),
     1 SCRAP(1)
      COMMON IN,IOT,IF1,IF2,IF3,IF4,IF5,IF6,IF7,IF8,IF9,IF10,IRECU,IRECT
      ROOT(X2)=SQRT(1.+B**2+2.*B*C*(X1+X2)+C**2*(X1**2+2.*X1*X2+X2**2))
      FP(X2)=-ROOTT-(X2-X1)*(C**2*(X1+X2)+B*C)/ROOTT
      F3(X)=A+B*X+C*X**2
C
C
C     THE STREAMWISE DISTRIBUTIONS OF DUCT RADIUS AND DUCT WALL SLOPE
C     ARE COMPUTED BELOW.
C
      READ(IN,10)JRADL
   10 FORMAT(10I2)
C
C     IF JRADL IS ZERO THESE DISTRIBUTIONS ARE READ IN DIRECTLY. IF
C     JRADL IS NONZERO THE WALL IS ASSUMED TO BE CONTOURED ACCORDING TO
C     THE EQUATION R = A + B*X +C*X**2. THEREFORE, COEFFICIENTS A, B
C     AND C ARE READ IN AND THE DISTRIBUTIONS OF DUCT RADIUS AND WALL
C     SLOPE ARE COMPUTED. FOR THE PURPOSES OF THE ABOVE EQUATION X AND
C     R ARE MEASURED ALONG AND NORMAL TO THE DUCT CENTRE LINE WITH
C     X = 0 CORRESPONDING TO THE INJECTION SLOT ENTRANCE.
C
      IF(JRADL)20,100,20
C
C     JRADL NONZERO
C
   20 READ(IN,110)A,B,C
      MD2=1.0001*(D2/DX)
      MLONG=M+MD2
      X1=0.
      Y1=A
      DO 90 K=2,MLONG
      X2=X1+DX/SQRT(1.+B**2+4.*B*C*X1+4.*(C*X1)**2)*12.
      DO 40 J=1,20
      ROOTT=ROOT(X2)
      FX2=12.*DX-ROOTT*(X2-X1)
      IF(ABS(FX2/DX/12.)-0.0001)60,60,30
   30 X2=X2-FX2/FP(X2)
   40 CONTINUE
      WRITE(IOT,50)
   50 FORMAT(///10X,'***  FATAL ERROR IN SUBROUTINE FLMN2.  CONVERGENCE
     1CANNOT BE ACHIEVED IN THE CALCULATION OF RDIUS AND ALPHA.'/15X,
     2 'JOB ABORTED.')
      STOP
   60 X1=X2
      IF(K-MD2)90,70,80
   70 RADUP=F3(X2)
      ALPHU=ATAN(B+2.*C*X2)
      GO TO 90
   80 JLOC=K-MD2
      RDIUS(JLOC)=F3(X2)
      ALPHA(JLOC)=ATAN(B+2.*C*X2)
   90 CONTINUE
      GO TO 120
C
C     JRADL ZERO
C
  100 READ(IN,110)RADUP,(RDIUS(J),J=1,M)
  110 FORMAT(8F10.6)
      READ(IN,110)ALPHU,(ALPHA(J),J=1,M)
  120 CONTINUE
C
C
C     THE STREAMWISE DISTRIBUTION OF WALL BLEED VELOCITY IS ESTABLISHED
C     BELOW.
C
      M1=M-1
      READ(IN,10)JV
C
C     IF JV IS ZERO THE DISTRIBUTION IS READ IN DIRECTLY. IF JV IS NON-
C     ZERO THE BLEED VELOCITY AT THE POINT OF INJECTION AND THE LINEAR
C     GRADIENT OF BLEED VELOCITY ARE READ IN. THESE QUANTITIES ARE USED
C     TO COMPUTE THE REQUIRED DISTRIBUTION.
C
      IF(JV)130,150,130
C
C     JV NONZERO
C
  130 READ(IN,110)VWALL(1),DVDX
      DO 140 J=1,M1
  140 VWALL(J+1)=VWALL(1)+DVDX*DX*J*12.
      GO TO 160
C
C     JV ZERO
C
  150 READ(IN,110)(VWALL(J),J=1,M)
  160 CONTINUE
C
C
C     THE STREAMWISE DISTRIBUTION OF FREE-STREAM TEMPERATURE IS ESTAB-
C     LISHED BELOW.
C
      READ(IN,10)JT
C
C     IF JT IS ZERO THE DISTRIBUTION IS READ IN DIRECTLY. IF JT IS NON-
C     ZERO THE FREE-STREAM TEMPERATURE AT THE POINT OF INJECTION AND
C     THE LINEAR GRADIENT OF TEMPERATURE ARE READ IN. THESE QUANTITIES
C     ARE USED TO COMPUTE THE REQUIRED DISTRIBUTION.
C
      IF(JT)210,230,210
C
C     JT NONZERO
C
  210 READ(IN,111)TINF(1),DTDX
  111 FORMAT(7F11.6)
      DO 220 J=1,M1
  220 TINF(J+1)=TINF(1)+DTDX*DX*J*12.
      GO TO 240
C
C     JT ZERO
C
  230 READ(IN,110)(TINF(J),J=1,M)
  240 CONTINUE
C
C
C     THE STATIC PRESSURES IN EACH OF THE MAIN AND INJECTED STREAMS,
C     ONE STATION UPSTREAM OF THE POINT OF INJECTION, ARE READ IN BELOW.
C
      READ(IN,245)PSLOT,PMAIN
  245 FORMAT(7F15.10)
C
C
C     THE DISTRIBUTIONS OF STATIC PRESSURE AND FREE-STREAM VELOCITY ARE
C     ESTABLISHED BELOW.
C
      READ(IN,10)JSEP
C
C     IF JSEP IS ZERO THESE DISTRIBUTIONS ARE READ IN DIRECTLY. IF JSEP
C     IS NONZERO THEN ONE DISTRIBUTION IS ESTABLISHED FROM VARIOUS IN-
C     PUTS AND THE OTHER IS COMPUTED USING BERNOULLI'S EQUATION FOR IN-
C     VISCID FLOW IN THE FREE STREAM. VARIOUS CASES ARE PRESENTED BELOW.
C
      IF(JSEP)250,410,250
C
C     JSEP NONZERO
C
  250 READ(IN,10)JPAR
C
C     IF JPAR IS ZERO THE FREE-STREAM VELOCITY AT THE POINT OF INJECTION
C     AND THE DISTRIBUTION OF STATIC PRESSURE ARE USED TO CALCULATE THE
C     DISTRIBUTION OF FREE-STREAM VELOCITY. IF JPAR IS NONZERO THE STAT-
C     IC PRESSURE AT THE POINT OF INJECTION AND THE DISTRIBUTION OF
C     FREE-STREAM VELOCITY ARE USED TO CALCULATE THE DISTRIBUTION OF
C     STATIC PRESSURE.
C
      IF(JPAR)350,260,350
C
C     JSEP NONZERO, JPAR ZERO
C
  260 READ(IN,110)UINF(1)
      READ(IN,10)JPRES
C
C     IF JPRES IS ZERO THE STREAMWISE DISTRIBUTION OF STATIC PRESSURE
C     IS READ IN DIRECTLY. IF JPRES IS NONZERO THE STATIC PRESSURE AT
C     THE POINT OF INJECTION AND THE LINEAR STATIC PRESSURE GRADIENT ARE
C     READ IN. THE DISTRIBUTION OF STATIC PRESSURE IS COMPUTED FROM THIS
C     INFORMATION.
C
      IF(JPRES)270,290,270
C
C     JSEP NONZERO, JPAR ZERO, JPRES NONZERO
C
  270 READ(IN,245)PRES(1),DPDX
      DO 280 J=1,M1
  280 PRES(J+1)=PRES(1)+DPDX*DX*J*12.
      GO TO 300
C
C     JSEP NONZERO, JPAR ZERO, JPRES ZERO
C
  290 READ(IN,110)(PRES(J),J=1,M)
  300 CONTINUE
C
C     THE DISTRIBUTION OF FREE-STREAM VELOCITY IS COMPUTED BELOW.
C
      DO 340 JL=2,M
      ARG=(PRES(1)*(1.+UINF(1)**2/2./GC/RGAS/TINF(1))-PRES(JL))
     1*2.*GC*RGAS*TINF(JL)/PRES(JL)
      IF(ARG)310,310,330
  310 WRITE(IOT,320)
  320 FORMAT(///10X,'***  FATAL ERROR IN SUBROUTINE FLMN2.'/15X,
     1 'UNREALISTIC FREE-STREAM CONDITIONS.'/15X,'JOB ABORTED.')
      STOP
  330 UINF(JL)=SQRT(ARG)
  340 CONTINUE
      GO TO 420
C
C     JSEP NONZERO, JPAR NONZERO
C
  350 READ(IN,110)PRES(1)
      READ(IN,10)JU
C
C     IF JU IS ZERO THE STREAMWISE DISTRIBUTION OF FREE-STREAM VELOCITY
C     IS READ IN DIRECTLY. IF JU IS NONZERO THE FREE-STREAM VELOCITY AT
C     THE POINT OF INJECTION AND THE LINEAR GRADIENT OF FREE-STREAM
C     VELOCITY ARE READ IN. THE DISTRIBUTION OF FREE-STREAM VELOCITY IS
C     COMPUTED FROM THIS INFORMATION.
C
      IF(JU)360,380,360
C
C     JSEP NONZERO, JPAR NONZERO, JU NONZERO
C
  360 READ(IN,110)UINF(1),DUEDX
      DO 370 J=1,M1
  370 UINF(J+1)=UINF(1)+DUEDX*DX*J*12.
      GO TO 390
C
C     JSEP NONZERO, JPAR NONZERO, JU ZERO
C
  380 READ(IN,110)(UINF(J),J=1,M)
  390 CONTINUE
C
C     THE DISTRIBUTION OF STATIC PRESSURE IS COMPUTED BELOW.
C
      DO 400 JL=2,M
  400 PRES(JL)=PRES(1)*(1.+UINF(1)**2/2./GC/RGAS/TINF(1))/
     1    (1.+UINF(JL)**2/2./GC/RGAS/TINF(JL))
      GO TO 420
C
C     JSEP ZERO
C
  410 READ(IN,110)(UINF(J),J=1,M)
      READ(IN,110)(PRES(J),J=1,M)
  420 CONTINUE
C
C
C     THE STREAMWISE DISTRIBUTIONS ESTABLISHED ABOVE ARE PRINTED OUT
C     BELOW, IF THIS OPTION HAS BEEN SPECIFIED BY THE USER.
C
```

Figure A-1: A Documented Listing for Program Film (Page 2).

```
      IF(JPRN)430,560,430
  430 WRITE(IOT,440)
  440 FORMAT(//5X,'5) STREAMWISE BOUNDARY CONDITIONS '//10X,'-STREAMWISE
     1 DISTRIBUTION OF FREE-STREAM VELOCITY:'//11X,'X (INCHES)',43X,
     2 'VELOCITY U (FPS)')
      CALL OTPT1 (D2,DX,M,UINF)
      WRITE(IOT,450)
  450 FORMAT(/10X,'-STREAMWISE DISTRIBUTION OF STATIC PRESSURE:'//
     1 11X,'X (INCHES)',39X,'STATIC PRESSURE P (PSIA)')
      CALL OTPT1 (D2,DX,M,PRES)
      WRITE(IOT,460)
  460 FORMAT(/10X,'-STREAMWISE DISTRIBUTION OF FREE-STREAM TEMPERATURE:'
     1 //11X,'X (INCHES)',41X,'TEMPERATURE T (''R)')
      CALL OTPT1 (D2,DX,M,TINF)
      WRITE(IOT,470)
  470 FORMAT(/10X,'-STREAMWISE DISTRIBUTION OF BLEED VELOCITY AT THE WAL
     1L:'//11X,'X (INCHES)',43X,'VELOCITY V (FPS)')
      CALL OTPT1 (D2,DX,M,VWALL)
      IF(COORD)490,490,510
  490 WRITE(IOT,500)
  500 FORMAT(/10X,'-STREAMWISE DISTRIBUTION OF CHANNEL HALF WIDTH:'//
     1 11X,'X  INCHES)',36X,'CHANNEL HALF WIDTH B (INCHES)')
      GO TO 530
  510 WRITE(IOT,520)
  520 FORMAT(/10X,'-STREAMWISE DISTRIBUTION OF CHANNEL RADIUS:'//
     1 11X,'X (INCHES)',38X,'CHANNEL RADIUS R (INCHES)')
  530 CALL OTPT1 (D2,DX,M,RDIUS)
      WRITE(IOT,540)
  540 FORMAT(/10X,'-STREAMWISE DISTRIBUTION OF WALL SLOPE:'//
     1 11X,'X (INCHES)',39X,'WALL SLOPE W (DEGREES)')
      RADEG=180./3.1415926
      DO 550 J=1,M
  550 SCRAP(J)=RADEG*ALPHA(J)
      CALL OTPT1 (D2,DX,M,SCRAP)
C
C
C     UNITS OF SOME PARAMETERS ARE ALTERED BELOW FOR CONSISTENCY.
C
  560 DO 570 J=1,M
      RDIUS(J)=RDIUS(J)/12.
  570 PRES(J)=PRES(J)*144.
      RADUP=RADUP/12.
      PSLOT=PSLOT*144.
      PMAIN=PMAIN*144.
C
C
      RETURN
      END

C******************************** FLMN3 ********************************
C******************************** FLMN3 ********************************
C******************************** FLMN3 ********************************
C
C
      SUBROUTINE FLMN3 (D1,DYY,DWIN,DWALL,XK,RGAS,M,XM,AA,Y,DY,JSTRT,
     1 JPRN,COORD,RAD1,RAD2,PSLOT,PMAIN,UM,UM1,UM2,VM,VM1,VM2,TM,TM1,
     2 TM2,RO,RO1,RO2,RDIUS,ALPHA,PRES,N1,N2,N,NC1,NC2,NC,NDIM,XOLD,
     3 YOLD,RLOC,RLOC1,RLOC2,RADUP,ALPHU)
C
C
C     THE PURPOSE OF THIS SUBROUTINE IS TO READ IN INFORMATION ABOUT
C     AND TO SET UP THE INFLOW BOUNDARY CONDITIONS, INCLUDING
C
C          1) GRID STEP SIZE,
C
C          2) TRANSVERSE POSITION,
C
C          3) TRANSVERSE VELOCITY,
C
C          4) TEMPERATURE,
C
C          5) DENSITY, AND
C
C          6) STREAMWISE VELOCITY.
C
C
      REAL NEW,MEW,MOM
      INTEGER COORD
      DIMENSION UM(1),UM1(1),UM2(1),VM(1),VM1(1),VM2(1),TM(1),TM1(1),
     1 TM2(1),RO(1),RO1(1),RO2(1),PRES(1),ALPHA(1),RDIUS(1),Y(1),DY(1),
     2 NC(1),XOLD(1),YOLD(1),RLOC(1),RLOC1(1),RLOC2(1)
      COMMON IN,IOT,IF1,IF2,IF3,IF4,IF5,IF6,IF7,IF8,IF9,IF10,IRECU,IRECT
C
C
      XK1=1./XK
      PI=3.1415926
C
C
C     THE DISTRIBUTIONS OF GRID STEP SIZE AND TRANSVERSE POSITION ARE
C     COMPUTED BELOW.
C
      DY10=DYY*10.
      DY100=DYY*100.
      DDWIN=D1+DWIN
      NC1=1.0001*(D1/2./DYY+1.0)
      NC11=NC1+1
      N1=1.0001*(NC1+D1/2./DY10)
      N11=N1+1
      N2=1.0001*(N1+DWIN/DY10)
      N21=N2+1
      NC2=1.0001*(NC1+1.5*D1/DY10)
      NC21=NC2+1
      N=1.0001*(NC2+(XM-2.*D1)/DY100)
      NDIF=N2-N1
      DO 10 J=1,NC1
      DY(J)=DYY
   10 Y(J)=(J-1)*DYY
      XNC1=Y(NC1)
      DO 20 J=NC11,NC2
      DY(J)=DY10
   20 Y(J)=XNC1+(J-NC1)*DY10
      XNC2=Y(NC2)
      DO 30 J=NC21,N
      DY(J)=DY100
   30 Y(J)=XNC2+(J-NC2)*DY100
C
C
C     THE TRANSVERSE DISTRIBUTIONS OF LOCAL RADIUS, BOTH AT THE POINT
C     OF INJECTION AND ONE STATION UPSTREAM OF INJECTION, ARE ESTABLISH-
C     ED BELOW. IF COORD IS POSITIVE THE FLOW IS AXISYMMETRIC. OTHER-
C     WISE THE FLOW IS PLANE AND ALL RADII ARE SET TO UNITY.
C
      IF(COORD)40,40,60
C
C     COORD NOT POSITIVE
C
   40 RAD1=1.0
      RAD2=1.0
      DO 50 J=1,N
      RLOC1(J)=1.0
   50 RLOC2(J)=1.0
      GO TO 80
C
C     COORD POSITIVE
C
   60 RAD1=RDIUS(1)
      RAD2=RADUP
      CSAL1=COS(ALPHA(1))
      CSAL2=COS(ALPHU)
      DO 70 J=1,N
      RLOC1(J)=RAD1-CSAL1*Y(J)
   70 RLOC2(J)=RAD2-CSAL2*Y(J)
C
C
C     IF JSTRT IS NONZERO, GRID INFORMATION FROM THE LAST RUN TO BE
C     EXECUTED IS READ IN AND STORED FOR FUTURE REFERENCE. THIS IS NEC-
C     ESSARY BECAUSE THE OUTFLOW BOUNDARY CONDITION FROM THE LAST RUN
C     TO BE EXECUTED WILL BECOME THE INFLOW BOUNDARY CONDITION FOR THE
C     PRESENT RUN.
C
   80 IF(JSTRT)90,110,90
C
C     JSTRT NONZERO
C
   90 READ(IF10'1)NOLD
      READ(IF9'1)(YOLD(J),J=1,NOLD)
      DO 100 J=1,NOLD
  100 YOLD(J)=YOLD(J)+DDWIN
C
C     JSTRT ZERO
C
C
C     THE TRANSVERSE DISTRIBUTIONS OF TRANSVERSE VELOCITY, BOTH AT THE
C     POINT OF INJECTION AND ONE STATION UPSTREAM OF INJECTION, ARE
C     ESTABLISHED BELOW. IF JSTRT IS ZERO THE ENTIRE VELOCITY PROFILE
C     IS SPECIFIED BY INPUT DATA. IF JSTRT IS NONZERO THE MAIN-STREAM
C     VELOCITY PROFILE WILL BE READ FROM A DISK FILE (OUTFLOW BOUNDARY
C     CONDITION FROM THE LAST RUN) AND ONLY THE VELOCITY PROFILE FOR
C     THE INJECTED STREAM WILL BE SPECIFIED BY INPUT DATA. THE MANNER
C     IN WHICH THIS INPUT DATA IS USED TO SET UP THE PROFILE IS SPECI-
C     FIED BY JVEL. IF JVEL IS ZERO THE PROFILE IS READ IN DIRECTLY. IF
C     JVEL IS NONZERO THE TRANSVERSE VELOCITY IS ASSUMED TO BE ZERO AND
C     THE PROFILE IS CONSTRUCTED TO THAT EFFECT.
C
  110 DO 310 JLOOP=1,2
      READ(IN,120)JVEL
  120 FORMAT(10I2)

      IF(JSTRT)130,210,130
C
C     JSTRT NONZERO
C
  130 GO TO (140,150),JLOOP
  140 NFILE=IF5
      GO TO 160
  150 NFILE=IF6
  160 CALL FLINK (Y,YOLD,VM,XOLD,N,NOLD,N2,NFILE)
C
      IF(JVEL)190,170,190
C
C     JSTRT NONZERO, JVEL ZERO
C
  170 READ(IN,180)(VM(J),J=1,N1)
  180 FORMAT(8F10.5)
      GO TO 250
C
C     JSTRT NONZERO, JVEL NONZERO
C
  190 DO 200 J=1,N1
  200 VM(J)=0.
      GO TO 250
C
C     JSTRT ZERO
C
  210 IF(JVEL)230,220,230
C
C     JSTRT ZERO, JVEL ZERO
C
  220 READ(IN,180)(VM(J),J=1,N)
      GO TO 250
C
C     JSTRT ZERO, JVEL NONZERO
C
  230 DO 240 J=1,N
  240 VM(J)=0.
C
C     THE TRANSVERSE COMPONENT OF VELOCITY ACROSS THE SLOT LIP WALL IS
C     SET TO ZERO, REGARDLESS OF THE USER SPECIFIED PROFILE.
C
  250 DO 260 J=N1,N2
  260 VM(J)=0.
C
C     THE VELOCITY PROFILES COMPUTED ABOVE ARE STORED IN INDIVIDUAL
C     ARRAYS.
C
      GO TO (270,290),JLOOP
  270 DO 280 J=1,N
  280 VM1(J)=VM(J)
      GO TO 310
  290 DO 300 J=1,N
  300 VM2(J)=VM(J)
  310 CONTINUE
C
```

Figure A-1: A Documented Listing for Program Film (Page 3).

```
C
C     THE TRANSVERSE DISTRIBUTIONS OF TEMPERATURE, BOTH AT THE POINT OF
C     INJECTION AND ONE STATION UPSTREAM OF INJECTION, ARE ESTABLISHED
C     BELOW. IF JSTRT IS ZERO THE ENTIRE TEMPERATURE PROFILE IS SPECI-
C     FIED BY INPUT DATA. IF JSTRT IS NONZERO THE MAIN-STREAM TEMPERA-
C     TURE PROFILE WILL BE READ FROM A DISK FILE (OUTFLOW BOUNDARY
C     CONDITION FROM THE LAST RUN) AND ONLY THE TEMPERATURE PROFILE FOR
C     THE INJECTED STREAM WILL BE SPECIFIED BY INPUT DATA. THE MANNER
C     IN WHICH THIS INPUT DATA IS USED TO SET UP THE PROFILE IS SPECI-
C     FIED BY JT. IF JT IS ZERO THE PROFILE IS READ IN DIRECTLY. IF JT
C     IS NONZERO THE UNIFORM TEMPERATURE OF THE STREAM(S) IS READ IN
C     AND THE PROFILE IS CONSTRUCTED TO THAT EFFECT.
C
C
      DO 520 JLOOP=1,2
      READ(IN,120)JT
C
      IF(JSTRT)320,390,320
C
C     JSTRT NONZERO
C
  320 GO TO (330,340),JLOOP
  330 NFILE=IF7
      GO TO 350
  340 NFILE=IF8
  350 CALL FLINK (Y,YOLD,TM,XOLD,N,NOLD,N2,NFILE)
C
      IF(JT)370,360,370
C
C     JSTRT NONZERO, JT ZERO
C
  360 READ(IN,180)(TM(J),J=1,N1)
      GO TO 440
C
C     JSTRT NONZERO, JT ZERO
C
  370 READ(IN,180)TINF2
      DO 380 J=1,N)
  380 TM(J)=TINF2
      GO TO 440
C
C     JSTRT ZERO
C
  390 IF(JT)410,400,410
C
C     JSTRT ZERO, JT ZERO
C
  400 READ(IN,180)(TM(J),J=1,N)
      GO TO 440
C
C     JSTRT ZERO, JT NONZERO
C
  410 READ(IN,180)TINF2,TINF1
      DO 420 J=1,N1
  420 TM(J)=TINF2
      DO 430 J=N2,N
  430 TM(J)=TINF1
C
C     THE TEMPERATURE IS VARIED LINEARLY ACROSS THE SLOT LIP WALL, RE-
C     GARDLESS OF THE USER SPECIFIED TEMPERATURE PROFILE.
C
  440 IF(NDIF-2)470,450,450
  450 JFRAC=0
      DIFF=TM(N2)-TM(N1)
      DO 460 J=N1, -2
      JFRAC=JFRAC
  460 TM(J)=TM(N1)+JFRAC*DIFF/NDIF
  470 CONTINUE
C
C     THE TEMPERATURE PROFILES COMPUTED ABOVE ARE STORED IN INDIVIDUAL
C     ARRAYS.
C
      GO TO (480,500),JLOOP
  480 WRITE(IF2'INECT)(TM(J),J=1,NDIM)
      DO 490 J=1,N
  490 TM1(J)=TM(J)
      GO TO 520
  500 DO 510 J=1,N
  510 TM2(J)=TM(J)
  520 CONTINUE
C
C
C     THE TRANSVERSE DISTRIBUTIONS OF STATIC DENSITY, BOTH AT THE POINT
C     OF INJECTION AND ONE STATION UPSTREAM OF INJECTION, ARE ESTABLISH-
C     ED BELOW.
C
      DO 580 J=1,N
      RO1(J)=PRES(1)/RGAS/TM1(J)
      IF(J-N1)530,530,540
  530 PR=PSLOT
      GO TO 570
  540 IF(J-N2)550,560,560
  550 PR=(PSLOT+PMAIN)/2.
      GO TO 570
  560 PR=PMAIN
  570 RO2(J)=PR/RGAS/TM2(J)
  580 CONTINUE
C
C
C     THE TRANSVERSE DISTRIBUTIONS OF STREAMWISE VELOCITY, BOTH AT THE
C     POINT OF INJECTION AND ONE STATION UPSTREAM OF INJECTION, ARE
C     ESTABLISHED BELOW. IF JSTRT IS ZERO THE ENTIRE VELOCITY PROFILE
C     IS SPECIFIED BY INPUT DATA. IF JSTRT IS NONZERO THE MAIN-STREAM
C     VELOCITY PROFILE WILL BE READ FROM A DISK FILE (OUTFLOW BOUNDARY
C     CONDITION FROM THE LAST RUN) AND ONLY THE VELOCITY PROFILE FOR THE
C     INJECTED STREAM WILL BE SPECIFIED BY INPUT DATA. THE MANNER IN
C     WHICH THIS INPUT DATA IS USED TO SET UP THE PROFILE IS SPECIFIED
C     BY JVEL. IF JVEL IS ZERO THE PROFILE IS READ IN DIRECTLY. IF JVEL
C     IS NONZERO VARIOUS PARAMETERS ARE READ IN AND USED WITH THE LAW OF
C     THE WALL AND LAW OF THE WAKE TO CONSTRUCT A REALISTIC VELOCITY
C     PROFILE.
C
      DO 1L70 JLOOP=1,2
C
C     THE DENSITY AND TEMPERATURE PROFILES ASSOCIATED WITH THE STREAM-
C     WISE STATION BEING PROCESSED ARE FETCHED BELOW.
C
      GO TO(590,610),JLOOP
  590 DO 600 J=1,N
      RO(J)=RO1(J)
  600 TM(J)=TM1(J)
      GO TO 630
  610 DO 620 J=1,N
      RO(J)=RO2(J)
  620 TM(J)=TM2(J)
  630 CONTINUE
C
C
C     FIRST THE PROFILE FOR THE INJECTED STREAM IS DEALT WITH.
C
      READ(IN,120)JVEL
C
      IF(JVEL)640,720,640
C
C     JVEL NONZERO
C
C     THE CORE VELOCITY IN THE SLOT, THE THICKNESS AND PROFILE PARAMETER
C     OF THE SLOT BOUNDARY LAYERS ARE READ IN BELOW.
C
  640 READ(IN,180)UDEL2,DELT2,PARM2
      DELT2=DELT2/12.
      JDEL2=1.0001*(DELT2/DYY+1.0)
      JDL2=JDEL2+1
      IF(NC1-JDL2)650,670,670
  650 WRITE(IOT,660)
  660 FORMAT(///10X,'***  FATAL ERROR IN SUBROUTINE FLMN3.' /15X,
     1 'SPECIFIED VALUE OF DELT2 IS TOO LARGE.'/15X,'JOB ABORTED.')
      STOP
C
C     THE LAW OF THE WALL (WITH VAN DRIEST'S MODIFICATION) AND THE LAW
C     OF THE WAKE ARE USED TO CONSTRUCT THE SLOT BOUNDARY LAYER ON THE
C     BOUNDING WALL.
C
  670 NEW=MEW(TM(1))/RO(1)
      CWALL=DELT2/NEW
      DWAL=DWALL+2.*PARM2*XK1
      CALL WLAW (UDEL2,XK1,CWALL,DWAL,UTAU)
      UM(1)=0.
      UPLS1=0.
      YPLS1=0.
      DO 680 KV=2,JDEL2
      YPLS2=UTAU*Y(KV)/NEW
      YPAVE=(YPLS1+YPLS2)/2.
      DYPLS=YPLS2-YPLS1
      BOT=1.+SQRT(1.+4.*XK*XK*YPAVE*YPAVE*(1.-EXP(-YPAVE/AA))**2)
      UPLS2=UPLS1+2./BOT*DYPLS
      UM(KV)=UTAU*(UPLS2+2.*PARM2*XK1*(SIN(PI/2.*Y(KV)/DELT2))**2)
      UPLS1=UPLS2
      YPLS1=YPLS2
  680 CONTINUE
      UFACT=UDEL2/UM(JDEL2)
      DO 690 JQ=1,JDEL2
  690 UM(JQ)=UM(JQ)*UFACT
C
C     THE LAW OF THE WALL (WITHOUT VAN DRIEST'S MODIFICATION) AND THE
C     LAW OF THE WAKE ARE USED TO CONSTRUCT THE SLOT BOUNDARY LAYER ON
C     THE SLOT LIP WALL. VAN DRIEST'S MODIFICATION IS NOT REQUIRED
C     HERE SINCE SUCH FINE STRUCTURE IS IMMEDIATELY DESTROYED IN THE
C     FREE SHEAR LAYER.
C
      JDL10=1.0001*(DELT2/DY10+1.0)
      KDEL2=N11-JDL10
      KDL2=KDEL2-1
      CWAL=UTAU/NEW
      DO 700 KVV=2,JDL10
      KV=N11-KVV
      YY=(KVV-1)*DY10
      UM(KV)=UTAU*(XK1*ALOG(CWAL*YY)+DWALL+2.*PARM2*XK1*
     1 (SIN(PI/2.*YY/DELT2))**2)
  700 CONTINUE
C
C     THE CORE VELOCITY BETWEEN SLOT BOUNDARY LAYERS IS INITIALIZED
C     BELOW.
C
      DO 710 J=JDL2,KDL2
  710 UM(J)=UDEL2
      GO TO 780
C
C     JVEL ZERO
C
  720 READ(IN,180)(UM(J),J=1,N1)
C
C     THE CORE VELOCITY AND SLOT BOUNDARY LAYER THICKNESS ARE IDENTI-
C     FIED BELOW.
C
      UDEL2=0.0
      DO 740 J=1,N1
      IF(UM(J)-UDEL2)760,740,730
  730 JDEL2=J
      UDEL2=UM(J)
  740 CONTINUE
      WRITE(IOT,750)
  750 FORMAT(///10X,'***  FATAL ERROR IN SUBROUTINE FLMN3.' /15X,
     1 'UNREALISTIC VELOCITY PROFILE.'/15X,'JOB ABORTED.')
      STOP
  760 JDEL2=(JDEL2+J-1)/2.
      JDL2=JDEL2+1
      IF(NC1-JDL2)650,770,770
  770 DELT2=Y(JDEL2)
C
C     VARIOUS BOUNDARY LAYER PARAMETERS ARE EVALUATED BY INTEGRATING
C     THE VELOCITY PROFILE. THESE INCLUDE THE DISPLACEMENT THICKNESS,
C     MOMENTUM DEFICIT THICKNESS AND THE VELOCITY PROFILE SHAPE FACTOR.
C
  780 GO TO (790,800),JLOOP
  790 RAD=RAD1
      ALPH=ALPHA(1)
      GO TO 810
  800 RAD=RAD2
      ALPH=ALPHU
  810 NC(1)=1
      NC(2)=JDL2
      NC(3)=0
      NC(4)=0
```

Figure A-1: A Documented Listing for Program Film (Page 4).

```
      CALL BLINT (NC,DY,Y,RAD,UM,RO,DISP,MOM,H,COORD,ALPH,0.0)
      GO TO (820,830),JLOOP
  820 SDEL1=12.*DELT2
      SMOM1=12.*MOM
      SDIS1=12.*DISP
      SH1=H
      SUT1=UTAU
      GO TO 840
  830 SDEL2=12.*DELT2
      SMOM2=12.*MOM
      SDIS2=12.*DISP
      SH2=H
      SUT2=UTAU
C
C
C     SECONDLY, THE PROFILE FOR THE MAIN STREAM IS DEALT WITH.
C
  840 IF(JSTRT)1060,850,1060
C
C     JSTRT ZERO
C
  850 READ(IN,120)JVEL
C
      IF(JVEL)860,990,860
C
C     JSTRT ZERO, JVEL NONZERO
C
C     THE THICKNESS OF THE MAIN-STREAM BOUNDARY LAYER IS READ IN BELOW.
C
  860 READ(IN,180)DELT1
      DELT1=DELT1/12.
      IF(DELT1-D1+DWIN)870,870,880
  870 JDEL1=1.0001+(DELT1/DY10+N2)
      GO TO 920
  880 IF(DELT1-XM+DDWIN)910,890,890
  890 WRITE(IOT,900)
  900 FORMAT(///10X,'***  FATAL ERROR IN SUBROUTINE FLMNS.'/15X,
     1 'SPECIFIED VALUE OF DELT1 IS TOO LARGE FOR THE GRID SIZE.'/15X,
     2 'JOB ABORTED.')
      STOP
  910 JDEL1=1.0001+(NC2+(DELT1-D1+DWIN)/DY100)
  920 JDL1=JDEL1+1
      NEW=MEW(TM(N2))/RO(N2)
C
      READ(IN,120)JDAT
C
      IF(JDAT)930,950,930
C
C     JSTRT ZERO, JVEL NONZERO, JDAT NONZERO
C
C     THE MAIN-STREAM CORE VELOCITY AND COLE'S PROFILE PARAMETER ARE
C     READ IN BELOW. THESE WILL BE USED TO CONSTRUCT THE MAIN-STREAM
C     VELOCITY PROFILE.
C
  930 READ(IN,940)UDEL1,PARM1
  940 FORMAT(5F15.10)
      CWALL=DELT1/NEW
      DWAL=DWALL+2.*PARM1*XK1
      CALL WLAW (UDEL1,XK1,CWALL,DWAL,UTAU)
      GO TO 960
C
C     JSTRT ZERO, JVEL NONZERO, JDAT ZERO
C
C     THE MAIN-STREAM CORE VELOCITY AND SKIN FRICTION COEFFICIENT ARE
C     READ IN BELOW. THESE WILL BE USED TO CONSTRUCT THE MAIN-STREAM
C     VELOCITY PROFILE.
C
  950 READ(IN,940)UDEL1,CF
      UTAU=UDEL1*SQRT(CF/2.)
      PARM1=XK/2.*(UDEL1/UTAU-XK1*ALOG(DELT1*UTAU/NEW)-DWALL)
C
C     THE LAW OF THE WALL (WITHOUT VAN DRIEST'S MODIFICATION) AND THE
C     LAW OF THE WAKE ARE USED TO CONSTRUCT THE VELOCITY PROFILE
C     THROUGHOUT THE MAIN-STREAM LAYER. VAN DRIEST'S MODIFICATION IS
C     NOT REQUIRED HERE SINCE SUCH FINE STRUCTURE IS IMMEDIATELY DES-
C     TROYED IN THE FREE SHEAR LAYER.
C
  960 DO 970 KV=N21,JDEL1
      YY=Y(KV)-DDWIN
      UM(KV)=UTAU*(XK1*ALOG(UTAU*YY/NEW)+DWALL+2.*PARM1*XK1*(SIN(PI/2.
     1 *YY/DELT1))**2)
  970 CONTINUE
C
C     THE MAIN-STREAM CORE VELOCITY, ABOVE THE MAIN-STREAM BOUNDARY
C     LAYER, IS INITIALIZED BELOW.
C
      DO 980 J=JDL1,N
  980 UM(J)=UDEL1
      GO TO 1020
C
C     JVEL NONZERO
C
  990 READ(IN,180)(UM(J),J=N2,N)
C
C     THE MAIN-STREAM BOUNDARY LAYER THICKNESS AND CORE VELOCITY ARE
C     IDENTIFIED BELOW.
C
      UDEL1=0.0
      DO 1010 J=N2,N
      IF(UM(J)-UDEL1)1010,1010,1000
 1000 JDEL1=J
      UDEL1=UM(J)
 1010 CONTINUE
      JDL1=JDEL1+1
      DELT1=Y(JDEL1)-DDWIN
C
C     VARIOUS BOUNDARY LAYER PARAMETERS ARE EVALUATED BY INTEGRATING
C     THE VELOCITY PROFILE. THESE INCLUDE THE DISPLACEMENT THICKNESS,
C     MOMENTUM DEFICIT THICKNESS AND VELOCITY PROFILE SHAPE FACTOR.
C
 1020 IF(JDL1-NC2)1040,1040,1030
 1030 NC(1)=N2
      NC(2)=NC2
      NC(3)=JDL1
      NC(4)=0
      GO TO 1050
 1040 NC(1)=N2
      NC(2)=JDL1
      NC(3)=0
      NC(4)=0
 1050 CALL BLINT (NC,DY,Y,RAD,UM,RO,DISP,MOM,H,COORD,ALPH,DDWIN)
      GO TO 1100
C
C     JSTRT NONZERO
C
 1060 GO TO (1070,1080),JLOOP
 1070 NFILE=IF3
      GO TO 1090
 1080 NFILE=IF4
 1090 CALL FLINK (Y,YOLD,UM,XOLD,N,NOLD,N2,NFILE)
 1100 DO 1110 J=N1,N2
 1110 UM(J)=0.
      GO TO (1120,1150),JLOOP
 1120 WRITE(IF1'IRECU)(UM(J),J=1,NDIM)
      PDEL1=12.*DELT1
      PMOM1=12.*MOM
      PDIS1=12.*DISP
      PH1=H
      PUT1=UTAU
      DO 1130 J=1,N
 1130 UM1(J)=UM(J)
      XMASS=0.0
      DO 1140 J1=2,N1
      RRAVE=(RLOC1(J1)+RLOC1(J1-1))/2./RAD1
      ROAVE=(RO(J1)+RO(J1-1))/2.
      UAVE=(UM(J1)+UM(J1-1))/2.
 1140 XMASS=XMASS+ROAVE*UAVE*DY(J1)*RRAVE
      GO TO 1170
 1150 PDEL2=12.*DELT1
      PMOM2=12.*MOM
      PDIS2=12.*DISP
      PH2=H
      PUT2=UTAU
C
C
C     THE STREAMWISE VELOCITY ACROSS THE SLOT LIP WALL IS SET TO ZERO,
C     REGARDLESS OF USER SPECIFIED INPUT.
C
      DO 1160 J=1,N
 1160 UM2(J)=UM(J)
 1170 CONTINUE
C
C
C     INFORMATION ABOUT THE INFLOW BOUNDARY CONDITIONS IS PRINTED
C     BELOW, IF THIS OPTION HAS BEEN SPECIFIED BY THE USER.
C
      IF(JPRN)1200,1340,1200
 1200 WRITE(IOT,1210)
 1210 FORMAT(//5X,'A) INFLOW BOUNDARY CONDITIONS'//8X,
     1 'A) AT THE POINT OF INJECTION')
      WRITE(IOT,1220)
 1220 FORMAT(//11X,'-TRANSVERSE DISTRIBUTION OF STREAMWISE VELOCITY:'
     1 /1X,'Y (INCHES)',53X,'VELOCITY U (FPS)')
      CALL OTPT2 (N,Y,UM1)
      IF(JSTRT)1250,1230,1250
 1230 WRITE(IOT,1240)SDEL1,PDEL1,SDIS1,PDIS1,SMOM1,PMOM1,SH1,PH1,
     1 SUT1,PUT1
 1240 FORMAT(//49X,'BOUNDARY LAYER AND RELATED PARAMETERS'//37X,
     1 'PARAMETER',36X,'SECONDARY         PRIMARY'/84X,'STREAM',10X,
     2 'STREAM'//25X,'BOUNDARY LAYER THICKNESS (INCHES)',21X,E14.7,2X,
     3 E14.7/25X,'DISPLACEMENT THICKNESS (INCHES)',23X,E14.7,2X,E14.7/
     4 25X,'MOMENTUM DEFICIT THICKNESS (INCHES)',19X,E14.7,2X,E14.7/
     5 25X,'VELOCITY PROFILE SHAPE FACTOR',25X,E14.7,2X,E14.7/25X,
     6 'FRICTION VELOCITY (FPS)',31X,E14.7,2X,E14.7)
      GO TO 1270
 1250 WRITE(IOT,1260)SDEL1,SDIS1,SMOM1,SH1,SUT1
 1260 FORMAT(// 49X,'BOUNDARY LAYER AND RELATED PARAMETERS'//37X,
     1 'PARAMETER',36X,'SECONDARY'/84X,'STREAM'
     2 //25X,'BOUNDARY LAYER THICKNESS (INCHES)',21X,E14.7
     3 /25X,'DISPLACEMENT THICKNESS (INCHES)',23X,E14.7/
     4 25X,'MOMENTUM DEFICIT THICKNESS (INCHES)',19X,E14.7/
     5 25X,'VELOCITY PROFILE SHAPE FACTOR',25X,E14.7/25X,
     6 'FRICTION VELOCITY (FPS)',31X,E14.7)
 1270 WRITE(IOT,1280)XMASS
 1280 FORMAT(/25X,'THE MASS ISSUING FROM THE SLOT IS',E14.7,' LBM/SEC'
     1 ,'/FT.')
      WRITE(IOT,1290)
 1290 FORMAT(//11X,'-TRANSVERSE DISTRIBUTION OF TRANSVERSE VELOCITY:'
     1 //1X,'Y (INCHES)',53X,'VELOCITY V (FPS)')
      CALL OTPT2 (N,Y,VM1)
      WRITE(IOT,1300)
 1300 FORMAT(//11X,'-TRANSVERSE DISTRIBUTION OF TEMPERATURE:' //
     1 1X,'Y (INCHES)',51X,'TEMPERATURE T (''R)')
      CALL OTPT2 (N,Y,TM1)
      WRITE(IOT,1310)
 1310 FORMAT(//8X,'B) ONE STATION UPSTREAM OF THE POINT OF INJECTION')
      WRITE(IOT,1220)
      CALL OTPT2 (N,Y,UM2)
      IF(JSTRT)1330,1320,1330
 1320 WRITE(IOT,1240)SDEL2,PDEL2,SDIS2,PDIS2,SMOM2,PMOM2,SH2,PH2,SUT2,
     1 PUT2
 1330 WRITE(IOT,1290)
      CALL OTPT2 (N,Y,VM2)
      WRITE(IOT,1300)
      CALL OTPT2 (N,Y,TM2)
C
C
 1340 RETURN
      END
C****************************** FMRCH ******************************
C****************************** FMRCH ******************************
C****************************** FMRCH ******************************
C
C
      SUBROUTINE FMRCH (UM,UM1,UM2,VM,VM1,VM2,RO,RO1,RO2,TM,TM1,TM2,Y,
     1 DY,JPRN,N,D1,D2,DX,XL,XM,PATM,TATM,XK,AA,RGAS,GC,DW,DWIN,COORD,
     2 RAD1,RAD2,ALPHA,RDIUS,UINF,TINF,VWALL,PRES,PSLOT,PMAIN,N1,N2,W,
     3 NC1,NC2,UMLAS,TMLAS,VSC,VTMB,RLOC,RLOC1,RLOC2,PART2,PART3,PART4,
     4 PART5,PART6,A,B,C,D,AP,AU,AU,PART7,ALM,ATRB,TNOLD,JHEAT,TWMAX,
     5 NDIM)
C
C
```

Figure A-1: A Documented Listing for Program Film (Page 5).

```
C     THE PURPOSE OF THIS SUBROUTINE IS TO COORDINATE THE DOWNSTREAM-
C     MARCHING PROCESS. THIS IS ACHIEVED BY
C
C           A) MONITORING THE CONVERGENCE OF THE STREAMWISE VELOCITY,
C              EDDY-VISCOSITY AND TEMPERATURE PROFILES, AND
C
C           B) STEPPING THE SOLUTION PROCEDURE FROM ONE STREAMWISE
C              STATION TO THE NEXT.
C
C
      INTEGER COORD
      REAL MEW
      DIMENSION UM(1),UM1(1),UM2(1),VM(1),VM1(1),VM2(1),RO(1),RO1(1),
     1 RO2(1),TM(1),TM1(1),TM2(1),Y(1),DY(1),ALPHA(1),RDIUS(1),UINF(1),
     2 TINF(1),VWALL(1),PRES(1),VSC(1),VTRB(1),UMLAS(1),ALM(1),ATRB(1),
     3 TMLAS(1),RLOC(1),RLOC1(1),RLOC2(1),PART2(1),THOLD(1),PART7(1),
     4 PART3(1),PART4(1),PART5(1),PART6(1),A(1),B(1),C(1),D(1),AP(1),
     5 AQ(1),AU(1)
      COMMON IN,IOT,IF1,IF2,IF3,IF4,IF5,IF6,IF7,IF8,IF9,IF10,IRECU,IRECT
C
C
      CONMT=1.00
      UMLIM=0.0001
      TMLIM=0.0001
      NM1=N-1
      KOGEN=0
C
C     ARRAY PART4 IS LOADED BELOW.
C
      DY2DX=2.*DY(NC1)*DY(NC1)/DX
      DO 10 J=1,NC1
   10 PART4(J)=DY2DX
      NC11=NC1+1
      DY2DX=2.*DY(NC2)*DY(NC2)/DX
      DO 20 J=NC11,NC2
   20 PART4(J)=DY2DX
      NC21=NC2+1
      DY2DX=2.*DY(N)*DY(N)/DX
      DO 30 J=NC21,N
   30 PART4(J)=DY2DX
C
C
C     THE LOOP BELOW CONTROLS THE DOWNSTREAM-MARCHING PROCEDURE BY
C     STEPPING THE SOLUTION THROUGH EACH STATION FROM 2 THROUGH M.
C
      DO 650 KOUNT=2,M
      X=(KOUNT-1)*DX+D2
C
C     HEADINGS ARE PRINTED BELOW, IF THIS OPTION HAS BEEN SPECIFIED BY
C     THE USER.
C
      IF(JPRN)40,60,40
   40 WRITE(IOT,50)KOUNT,X
   50 FORMAT('1',1X,'*** STATION NUMBER',I4,5X,'X =',F8.4,' FEET')
C
C     AT THE FIRST STATION DOWNSTREAM OF THE POINT OF INJECTION (I.E.,
C     KOUNT = 2) REASONABLE GUESSES MUST BE MADE AT VALUES IN ARRAYS
C     UM, VM, TM, UMLAS AND TMLAS. AT ALL OTHER STATIONS (I.E., KOUNT
C     > 2) VALUES FROM THE PREVIOUS STATION OR ITERATION WILL SUFFICE.
C
   60 IF(KOUNT-2)70,70,110
C
C     KOUNT = 2
C
   70 DO 80 J=1,N
      UM(J)=2.*UM1(J)-UM2(J)
      UMLAS(J)=UM(J)
      VM(J)=2.*VM1(J)-VM2(J)
      TM(J)=2.*TM1(J)-TM2(J)
   80 TMLAS(J)=TM(J)
      PM1=PRES(1)
      PM2=PMAIN
      IF(COORD)90,90,150
   90 RAD=1.0
      DO 100 J=1,N
      RLOC(J)=1.0
  100 PART2(J)=0.0
      GO TO 150
C
C     KOUNT > 2
C
  110 DO 120 J=1,N
      UM2(J)=UM1(J)
      UM1(J)=UM(J)
      UMLAS(J)=UM(J)
      VM2(J)=VM1(J)
      VM1(J)=VM(J)
      TM2(J)=TM1(J)
      TM1(J)=TM(J)
      TMLAS(J)=TM(J)
      RO2(J)=RO1(J)
      RO1(J)=RO(J)
  120 CONTINUE
      PM2=PM1
      PM1=PM
      IF(COORD)150,150,130
  130 DO 140 J=1,N
      RLOC2(J)=RLOC1(J)
  140 RLOC1(J)=RLOC(J)
      RAD2=RAD1
      RAD1=RAD
C
C
C     THE FOLLOWING COMPUTATIONS ARE PERFORMED WHENEVER THE SOLUTION
C     ADVANCES TO THE NEXT STREAMWISE STATION, INCLUDING THE FIRST ONE.
C
  150 PM=PRES(KOUNT)
      VWAL=VWALL(KOUNT)
      UFREE=UINF(KOUNT)
      TFREE=TINF(KOUNT)
C
C     ARRAYS PART5 AND PART6 ARE LOADED BELOW.
C
      IF(KOUNT-2)160,160,200
  160 PTRM=3.*PM-4.*PM1+PSLOT
      DO 170 J=1,N1
  170 PART6(J)=PART4(J)*GC*PTRM
      PTRM=3.*PM-4.*PM1+0.5*PSLOT+0.5*PMAIN
      DO 180 J=N1,N2
  180 PART6(J)=PART4(J)*GC*PTRM
      PTRM=3.*PM-4.*PM1+PMAIN
      N21=N2+1
      DO 190 J=N21,N
  190 PART6(J)=PART4(J)*GC*PTRM
      GO TO 220
  200 PTRM=3.*PM-4.*PM1+PM2
      DO 210 J=1,N
  210 PART6(J)=PART4(J)*GC*PTRM
  220 DPDX=PTRM/2./DX
      DO 230 J=1,N
  230 PART5(J)=PART4(J)*(UM2(J)-4.*UM1(J))
C
C     IN THE CASE OF AXISYMMETRIC FLOW THE TRANSVERSE DISTRIBUTION OF
C     LOCAL RADIUS AND ARRAY PART2 ARE COMPUTED.
C
      IF(COORD)270,270,240
  240 RAD=RDIUS(KOUNT)
      COSAL=COS(ALPHA(KOUNT))
      DO 250 J=1,N
  250 RLOC(J)=RAD-COSAL*Y(J)
      DO 260 J=2,NM1
  260 PART2(J)=(RLOC(J+1)-RLOC(J-1))/RLOC(J)
  270 CONTINUE
C
C
C     THE FOLLOWING LOOP CYCLES THROUGH TEN ITERATIONS ATTEMPTING TO
C     SOLVE THE ENERGY EQUATION. THESE ITERATIONS ARE OMITTED IF THE
C     USER HAS SPECIFIED THAT THE ENERGY EQUATION WILL NOT BE INCLUDED
C     IN THE SOLUTION.
C
      DO 570 ITERT=1,10
      IF(JHEAT)280,310,280
C
C     HEADINGS ARE PRINTED BELOW, IF THIS OPTION HAS BEEN SPECIFIED BY
C     THE USER.
C
  280 IF(JPRN)290,310,290
  290 WRITE(IOT,300)ITERT
  300 FORMAT(///6X,'TEMPERATURE ITERATION NUMBER',I3)
C
C     THE TRANSVERSE DISTRIBUTION OF DENSITY AND KINEMATIC VISCOSITY, AS
C     WELL AS ARRAYS PART3 AND PART7, ARE COMPUTED BELOW.
C
  310 DO 320 J=1,N
      RO(J)=PM/RGAS/TM(J)
  320 VSC(J)=MEW(TM(J))/RO(J)
      DO 330 J=2,NM1
  330 PART3(J)=(RO(J+1)-RO(J-1))/RO(J)
      DO 340 J=1,N
  340 PART7(J)=PART4(J)*(TM2(J)-4.*TM1(J))
C
C
C     THE FOLLOWING LOOP CYCLES THROUGH TEN ITERATIONS ATTEMPTING TO
C     SOLVE THE MOMENTUM AND CONTINUITY EQUATIONS.
C
      FNMUL=1.0E+30
      DO 480 ITERU=1,10
C
C     HEADINGS ARE PRINTED BELOW, IF THIS OPTION HAS BEEN SPECIFIED BY
C     THE USER.
C
      IF(JPRN)350,370,350
  350 WRITE(IOT,360)ITERU
  360 FORMAT(//11X,'VELOCITY ITERATION NUMBER',I3)
C
C     SUBROUTINE FLMVU IS CALLED TO EVALUATE THE EDDY-VISCOSITY PRO-
C     FILE AND TO SOLVE THE MOMENTUM AND CONTINUITY EQUATIONS.
C
  370 CALL FLMVU (N,DX,DY,D2,JPRN,D1,COORD,DMIN,RAD,RAD1,RAD2,DPDX,
     1 KOGEN,NC1,NC2,Y,GC,UM,UM1,UM2,VM,RO,RO1,RO2,TM,VSC,VTRB,UFREE,
     2 VWAL,RLOC,RLOC1,RLOC2,PART2,PART3,PART4,PART5,PART6,UMLAS,A,B,
     3 C,D,AP,AQ,AU,DELT1)
C
C     CONVERGENCE OF THE STREAMWISE VELOCITY PROFILE IS CHECKED BELOW.
C     IF CONVERGENCE HAS OCCURRED THE ENERGY EQUATION WILL BE TACKLED
C     NEXT. IF NOT THE OLD STREAMWISE VELOCITY PROFILE WILL BE REPLACED
C     BY THE NEW PROFILE AND ANOTHER ITERATION WILL BE ATTEMPTED.
C
      FNRMU=0.0
      DO 380 J=2,N
  380 FNRMU=FNRMU+ABS(UM(J)-UMLAS(J))/UM(J)
      FNRMU=FNRMU/N
C
C     CONVERGENCE PARAMETERS ARE PRINTED BELOW, IF THIS OPTION HAS BEEN
C     SPECIFIED BY THE USER.
C
      IF(JPRN)390,410,390
  390 WRITE(IOT,400)FNRMU
  400 FORMAT(/11X,'VELOCITY FRACTIONAL DISPLACEMENT NORM =',E13.6)
  410 IF(FNRMU-UMLIM)490,490,420
  420 IF(ITERU-4)430,430,450
  430 FNMUL=FNRMU
      DO 440 J=1,N
  440 UMLAS(J)=UM(J)
      GO TO 480
  450 IF(FNRMU-CONMT*FNMUL)460,490,490
  460 FNMUL=FNRMU
      DO 470 J=1,N
  470 UMLAS(J)=UM(J)
  480 CONTINUE
C
C     SUBROUTINE FLMTD IS CALLED TO SOLVE THE ENERGY EQUATION, IF THIS
C     OPTION HAS BEEN SPECIFIED BY THE USER.
C
  490 IF(JHEAT)500,610,500
  500 CALL FLMTD (UM,VM,TM,TM1,TM2,VSC,VTRB,ALM,ATRB,RO,PART2,PART3,
     1 PART4,PART7,RLOC,A,B,C,D,AP,AQ,AU,DY,DX,N,NC1,NC2,THOLD,Y,DELT1,
     2 TFREE,KOUNT,TATM)
C
C     CONVERGENCE OF THE TEMPERATURE PROFILE IS CHECKED BELOW. IF CON-
C     VERGENCE HAS NOT OCCURRED THE OLD TEMPERATURE PROFILE IS REPLACED
C     BY THE NEW PROFILE AND ANOTHER ITERATION IS ATTEMPTED. IF CONVERG-
C     ENCE HAS OCCURRED THE PROCEDURE MOVES ON TO THE NEXT STREAMWISE
C     STATION.
```

Figure A-1: A Documented Listing for Program Film (Page 6).

```
C
      FNRMT=0.0
      DO 510 J=2,N
  510 FNRMT=FNRMT+ABS(TM(J)-TMLAS(J))/TM(J)
      FNRMT=FNRMT/N
C
C     CONVERGENCE PARAMETERS ARE PRINTED BELOW, IF THIS OPTION HAS BEEN
C     SPECIFIED BY THE USER.
C
      IF(JPRN)520,540,520
  520 WRITE(IOT,530)FNRMT,TM(1)
  530 FORMAT(//6X,'TEMPERATURE FRACTIONAL DISPLACEMENT NORM =',E13.6
     1 ,5X,'WALL TEMPERATURE =',E13.6,' ''R')
  540 IF(FNRMT-TMLIM)580,580,550
  550 DO 560 J=1,N
      UMLAS(J)=UM(J)
  560 TMLAS(J)=TM(J)
  570 CONTINUE
  580 CONTINUE
      WRITE(IF2'IRECT)(TM(J),J=1,NDIM)
C
C     THE FINAL TEMPERATURE PROFILE FOR THE STREAMWISE STATION BEING
C     PROCESSED IS PRINTED BELOW, IF THIS OPTION HAS BEEN SPECIFIED BY
C     THE USER.
C
      IF(JPRN)590,610,590
  590 WRITE(IOT,600)
  600 FORMAT(///53X,'TRANSVERSE DISTRIBUTION OF TEMPERATURE'//
     1 1X,'Y (INCHES)',52X,'TEMPERATURE T (''R)')
      CALL OTPT2 (N,Y,TM)
  610 CONTINUE
      WRITE(IF1'IRECU)(UM(J),J=1,NDIM)
C
C     THE FINAL STREAMWISE VELOCITY PROFILE FOR THE STREAMWISE STATION
C     BEING PROCESSED IS PRINTED BELOW, IF THIS OPTION HAS BEEN SPECIF-
C     IED BY THE USER.
C
      IF(JPRN)620,640,620
  620 WRITE(IOT,630)
  630 FORMAT(///49X,'TRANSVERSE DISTRIBUTION OF STREAMWISE VELOCITY'//
     1 1X,'Y (INCHES)',53X,'VELOCITY U (FPS)')
      CALL OTPT2 (N,Y,UM)
  640 CONTINUE
C
C     IF THE WALL TEMPERATURE HAS EXCEEDED THE SPECIFIED MAXIMUM ALLOW-
C     ABLE TEMPERATURE THE JOB IS TERMINATED IN A CONTROLLED AND USUAL
C     MANNER.
C
      IF(TM(1)-TWMAX)650,660,660
  650 CONTINUE
C
C

  660 RETURN
      END

C******************************* FLWVU *******************************
C******************************* FLWVU *******************************
C******************************* FLWVU *******************************
C
C
      SUBROUTINE FLWVU (N,DX,DY,D2,JPRN,DL,COORD,QWIN,RAD,RAD1,RAD2,
     1 DPDX,KDGEN,NC1,NC2,Y,GC,UM,UM1,UM2,VM,RO,RO1,RO2,TM,VSC,VTRB,
     2 UFREE,VWAL,NLOC,NLOC1,NLOC2,PART2,PART3,PART4,PART5,PART6,
     3 UMLAS,A,B,C,D,AP,AQ,AU,DELT1)
C
C
C     THE PURPOSE OF THIS SUBROUTINE IS TO CALCULATE THE DISTRIBUTION
C     OF STREAMWISE VELOCITY, TRANSVERSE VELOCITY AND EDDY VISCOSITY
C     THROUGHOUT THE BOUNDARY LAYER AT A GIVEN STREAMWISE STATION. THIS
C     IS ACIEVED BY
C
C           A) IDENTIFYING THE BOUNDARY LAYER TO BE OF THE WALL JET OR
C              CONVENTIONAL TYPE BY SEARCHING FOR A LOCAL VELOCITY
C              MAXIMUM,
C
C           B) CALCULATING AN EDDY-VISCOSITY PROFILE BASED ON A TWO-
C              LAYER MODEL WHICH EMPLOYS THE PRANDTL MIXING-LENGTH
C              HYPOTHESIS,
C
C           C) SOLVING A SYSTEM OF LINEAR ALGEBRAIC FINITE-DIFFERENCE
C              EQUATIONS WHICH APPROXIMATE THE DIFFERENTIAL EQUATION
C              FOR THE CONSERVATION OF MOMENTUM IN AN INCOMPRESSIBLE
C              TURBULENT BOUNDARY LAYER, AND
C
C           D) SOLVING THE CONTINUITY EQUATION IN FINITE-DIFFERENCE FORM
C              TO OBTAIN THE DISTRIBUTION OF TRANSVERSE VELOCITY THROUGH-
C              OUT THE BOUNDARY LAYER.
C
C
      INTEGER COORD
      REAL MEW,MEWAL
      DIMENSION UM(1),UM1(1),UM2(1),VM(1),TM(1),A(1),B(1),C(1),D(1),
     1 VSC(1),RO(1),RO1(1),RO2(1),VTRB(1),Y(1),DY(1),NLOC(1),NLOC1(1),
     2 NLOC2(1),PART2(1),PART3(1),PART4(1),PART5(1),PART6(1),UMLAS(1),
     3 AQ(1),AP(1),AU(1)
      COMMON IN,IOT,IF1,IF2,IF3,IF4,IF5,IF6,IF7,IF8,IF9,IF10,IRECU,IRECT
C
C
      NM1=N-1
      PI=3.1415926
      XLAMB=0.09
      AA=26.0
      XK=0.435
      XK2=XK*XK
      MEWAL=MEW(TM(1))
      ROWAL=RO(1)
C
C
C***************************** STEP 1 *********************************
C
C************** CALCULATING THE EDDY-VISCOSITY PROFILE ****************
C
C***************************** STEP 1 *********************************
C
C
```

```
C     THE EDGE OF THE BOUNDARY LAYER IS LOCATED BY IDENTIFYING THE
C     LOCATION WHERE THE STREAMWISE VELOCITY DIFFERS FROM THAT IN THE
C     FREE STREAM BY ONE PERCENT. IF SUCH A VELOCITY DOES NOT EXIST
C     THE JOB IS ABORTED. IF SUCH A VELOCITY DOES EXIST THE CORRESPOND-
C     ING BOUNDARY-LAYER THICKNESS IS CALCULATED.
C
      DO 10 J=1,NM1
      JDEL1=N-J
      QUANT=(UFREE-UM(JDEL1))/UFREE
      IF(ABS(QUANT)-0.010)10,30,30
   10 CONTINUE
      WRITE(IOT,20)
   20 FORMAT(///10X,'***  FATAL ERROR IN SUBROUTINE FLWVU.'/15X,
     1 'VELOCITY PROFILE IS ONE DIMENSIONAL.'/15X,'JOB ABORTED.')
      STOP
   30 IF(QUANT)50,50,40
   40 UDEL1=0.99*UFREE
      GO TO 60
   50 UDEL1=1.01*UFREE
   60 JDL11=JDEL1+1
      DELT1=Y(JDEL1)+(UDEL1-UM(JDEL1))/(UM(JDL11)-UM(JDEL1))*DY(JDL11)
C
C
C     A CHECK IS MADE TO DETERMINE WHETHER OR NOT THE WALL JET BOUNDARY
C     LAYER HAS ALREADY DEGENERATED TO A CONVENTIONAL WALL BOUNDARY
C     LAYER AT SOME PREVIOUS UPSTREAM LOCATION.
C
      IF(KDGEN)250,250,70
C
C
C**************** CASE 1. CONVENTIONAL BOUNDARY LAYER *****************
C
C     THE DISTANCE ABOVE THE WALL WHERE THE INNER AND OUTER LAYERS OF
C     THE BOUNDARY LAYER INTERSECT IS CALCULATED.
C
   70 YOUT=DELT1*XLAMB/XK
      DO 80 JOUT1=1,JDEL1
      IF(Y(JOUT1)-YOUT)80,80,100
   80 CONTINUE
      WRITE(IOT,90)
   90 FORMAT(///10X,'***  FATAL ERROR IN SUBROUTINE FLWVU.'/15X,
     1 'INCORRECT EDDY-VISCOSITY FORMULATION.'/15X,'JOB ABORTED.')
      STOP
  100 JOUT=JOUT1-1
C
C
C     THE FRICTION VELOCITY AT THE WALL IS CALCULATED.
C
      DUDYW=(18.*UM(2)-9.*UM(3)+2.*UM(4))/6./DY(2)
      IF(DUDYW)110,110,130
  110 WRITE(IOT,120)
  120 FORMAT(///10X,'***  FATAL ERROR IN SUBROUTINE FLWVU.'/15X,
     1 'VELOCITY GRADIENT AT THE WALL HAS GONE NEGATIVE.'/15X,
     2 'JOB ABORTED.')
      STOP
  130 UTAU=SQRT(VSC(1)*DUDYW)
C
C
C     THE EDDY-VISCOSITY PROFILE IN THE INNER LAYER IS CALCULATED
C     USING VAN DRIEST'S FORMULATION FOR THE MIXING LENGTH, MODIF-
C     ICATIONS TO ACCOUNT FOR PRESSURE-GRADIENT, HEAT AND MASS
C     TRANSFER EFFECTS ARE DUE TO CEBEC1.
C
      VTRB(1)=0.0
      IF(DPDX)150,140,150
  140 PPLUS=0.0
      GO TO 160
  150 PPLUS=-VSC(N)*GC/RO(N)/UTAU/UTAU/UTAU*DPDX
  160 IF(VWAL)190,170,190
C
C
C     WITH NO MASS TRANSFER AT THE WALL
C
  170 XN=SQRT(1.-11.8*VSC(1)/VSC(N)*RO(N)/ROWAL*PPLUS)
      DO 180 J=2,JOUT
      YY=Y(J)
      DUDY=(UM(J+1)-UM(J-1))/(DY(J+1)+DY(J))
      TERM=1.-EXP(-UTAU*YY/AA/VSC(J)*XN*SQRT(ROWAL/RO(J)))
      VTRB(J)=XK2*YY*YY*TERM*TERM*ABS(DUDY)
  180 CONTINUE
      GO TO 210
C
C
C     WITH MASS TRANSFER AT THE WALL
C
  190 VWPLS=VWAL/UTAU
      PRT1=RO(N)/VSC(N)/ROWAL/ROWAL*PPLUS/VWPLS
      PRT2=11.8*MEWAL*VWPLS
      DO 200 J=2,JOUT
      YY=Y(J)
      DUDY=(UM(J+1)-UM(J-1))/(DY(J+1)+DY(J))
      XMEWJ=MEW(TM(J))
      PRT3=EXP(PRT2/XMEWJ)
      XN=SQRT(XMEWJ*PRT1*(1.-PRT3)+PRT3)
      TERM=1.-EXP(-UTAU*YY/AA/VSC(J)*XN*SQRT(ROWAL/RO(J)))
      VTRB(J)=XK2*YY*YY*TERM*TERM*ABS(DUDY)
  200 CONTINUE
C
C
C     THE EDDY-VISCOSITY PROFILE IN THE OUTER LAYER IS CALCULATED
C     USING SPALDING AND PATANKAR'S RECOMMENDATION FOR THE MIXING
C     LENGTH IN AN ESCUDIER TWO-LAYER FORMULATION.
C
  210 YMIX=XLAMB*DELT1
      YMIX2=YMIX*YMIX
      DO 220 J=JOUT1,NM1
      DUDY=(UM(J+1)-UM(J-1))/(DY(J+1)+DY(J))
      VTRB(J)=YMIX2*ABS(DUDY)
  220 CONTINUE
      VTRB(N)=VTRB(NM1)
C
C
C     THE MAXIMUM VALUE OF EDDY VISCOSITY IS CALCULATED BY INTERPOLATING
C     BETWEEN GRID POINTS FOR THE VELOCITY GRADIENT AT THE LOCATION
C     WHERE INNER AND OUTER LAYERS INTERSECT.
C
```

Figure A-1: A Documented Listing for Program Film (Page 7).

```
      J1=JOUT-2
      J2=JOUT-1
      J3=JOUT
      J4=JOUT1
      J5=JOUT1+1
      J6=JOUT1+2
      DUDY1=(UM(J3)-UM(J1))/(DY(J3)+DY(J2))
      DUDY2=(UM(J4)-UM(J2))/(DY(J4)+DY(J3))
      DUDY3=(UM(J5)-UM(J3))/(DY(J5)+DY(J4))
      DUDY4=(UM(J6)-UM(J4))/(DY(J6)+DY(J5))
      DUDYM=GNINT (YOUT,Y(J2),Y(J3),Y(J4),Y(J5),
     1 DUDY1,DUDY2,DUDY3,DUDY4)
      VTMM=YMIX2*ABS(DUDYM)
C
C
C     INFORMATION ABOUT THE BOUNDARY LAYER IS PRINTED, IF THIS OPTION
C     HAS BEEN SPECIFIED BY THE USER.
C
      IF(JPRN)230,530,230
  230 WRITE(IOT,240)DELT1,UDEL1,UTAU,VTMM,YOUT
  240 FORMAT(/20X,'DELT1          UDEL1          UTAU          VTMM',
     1 '          YOUT '/16X,8E13.6)
      GO TO 530
C
C
C******************* CASE 2. WALL JET BOUNDARY LAYER ********************
C
C     A SEARCH IS CONDUCTED TO DEFINE THE 'JET' REGION OF THE WALL JET
C     BOUNDARY LAYER. THIS IS ACCOMPLISHED BY LOCATING A LOCAL VELOCITY
C     MAXIMUM IN THE VELOCITY PROFILE. IF SUCH A POINT DOES NOT EXIST
C     IT IS ASSUMED THAT THE WALL JET BOUNDARY LAYER HAS DEGENERATED
C     TO A CONVENTIONAL TURBULENT BOUNDARY LAYER AND THE 'CASE 1'
C     FORMULATION FOR EDDY VISCOSITY (ABOVE) IS APPLIED FROM HERE ON IN.
C     IF A LOCAL VELOCITY MAXIMUM IS LOCATED THE TWO-LAYER MODEL IS
C     APPLIED TO EACH OF THE JET REGION AND THE TOTAL BOUNDARY LAYER
C     IN THE CODING THAT FOLLOWS.
C
C
C     THE SEARCH FOR A LOCAL WALL JET VELOCITY MAXIMUM IS CONDUCTED
C     BELOW.
C
  250 CONTINUE
      JUMP=1
      JSTR=1+JUMP
      DO 260 J=JSTR,N,JUMP
      JJUMP=J-JUMP
      DU=UM(J)-UM(JJUMP)
      DUDY=DU/(Y(J)-Y(JJUMP))
      IF(DUDY)280,280,260
  260 CONTINUE
  270 KDGEN=1
      GO TO 70
  280 JDEL2=(J+JJUMP)/2.
      IF(JDEL2-JDEL1)290,270,270
  290 JDL21=JDEL2+1
      DELT2=Y(JDEL2)
      UDEL2=UM(JDEL2)
C
C
C     THE FRICTION VELOCITY AT THE WALL IS CALCULATED.
C
      DUDYM=(18.*UM(2)-9.*UM(3)+2.*UM(4))/6./DY(2)
      IF(DUDYM)300,300,310
  300 WRITE(IOT,120)
      STOP
  310 UTAU=SQRT(VSC(1)*DUDYM)
C
C
C     THE EDDY-VISCOSITY PROFILE IN THE INNER LAYER OF THE JET IS
C     CALCULATED USING VAN DRIEST'S FORMULATION FOR THE MIXING LENGTH.
C     MODIFICATIONS TO ACCOUNT FOR PRESSURE-GRADIENT, HEAT AND MASS
C     TRANSFER EFFECTS ARE DUE TO CEBECI.
C
      VTRB(1)=0.0
      YOUT=DELT2*XLAMB/XK
      DO 320 JOUT1=1,JDEL2
      IF(Y(JOUT1)-YOUT)320,320,330
  320 CONTINUE
      WRITE(IOT,90)
      STOP
  330 JOUT=JOUT1-1
      IF(DPDX)350,340,350
  340 PPLUS=0.0
      GO TO 360
  350 PPLUS=-VSC(N)*GC/RO(N)/UTAU/UTAU/UTAU*DPDX
  360 IF(VWAL)390,370,390
C
C
C     WITH NO MASS TRANSFER AT THE WALL
C
  370 XN=SQRT(1.-11.8*VSC(1)/VSC(N)*RO(N)/ROWAL*PPLUS)
      DO 380 J=2,JOUT
      YY=Y(J)
      DUDY=(UM(J+1)-UM(J-1))/(DY(J+1)+DY(J))
      TERM=1.-EXP(-UTAU*YY/AA/VSC(J)*XN*SQRT(ROWAL/RO(J)))
  380 VTRB(J)=XK2*YY*YY*TERM*TERM*ABS(DUDY)
      GO TO 410
C
C
C     WITH MASS TRANSFER AT THE WALL
C
  390 VWPLS=VWAL/UTAU
      PRT1=RO(N)/VSC(N)/ROWAL/ROWAL*PPLUS/VWPLS
      PRT2=11.8*MEWAL*VWPLS
      DO 400 J=2,JOUT
      YY=Y(J)
      DUDY=(UM(J+1)-UM(J-1))/(DY(J+1)+DY(J))
      XMEWJ=MEW(TM(J))
      PRT3=EXP(PRT2/XMEWJ)
      XN=SQRT(XMEWJ*PRT1*(1.-PRT3)+PRT3)
      TERM=1.-EXP(-UTAU*YY/AA/VSC(J)*XN*SQRT(ROWAL/RO(J)))
  400 VTRB(J)=XK2*YY*YY*TERM*TERM*ABS(DUDY)
C
C
C     THE MAXIMUM VALUE OF EDDY VISCOSITY IN THE JET IS CALCULATED
C     BY INTERPOLATING BETWEEN GRID POINTS FOR THE VELOCITY GRADIENT
C     WHERE INNER AND OUTER LAYERS INTERSECT.
C
  410 J1=JOUT-2
      J2=JOUT-1
      J3=JOUT
      J4=JOUT1
      J5=JOUT1+1
      J6=JOUT1+2
      DUDY1=(UM(J3)-UM(J1))/(DY(J3)+DY(J2))
      DUDY2=(UM(J4)-UM(J2))/(DY(J4)+DY(J3))
      DUDY3=(UM(J5)-UM(J3))/(DY(J5)+DY(J4))
      DUDY4=(UM(J6)-UM(J4))/(DY(J6)+DY(J5))
      DUDYM=GNINT (YOUT,Y(J2),Y(J3),Y(J4),Y(J5),
     1 DUDY1,DUDY2,DUDY3,DUDY4)
      VTMJ=XLAMB*XLAMB*DELT2*DELT2*ABS(DUDYM)
C
C
C     THE EDDY-VISCOSITY PROFILE IN THE OUTER REGION OF THE TOTAL
C     BOUNDARY LAYER IS CALCULATED USING SPALDING AND PATANKAR'S
C     RECOMMENDATION FOR THE MIXING LENGTH IN AN ESCUDIER TWO-LAYER
C     FORMULATION.
C
      YOMIN=XLAMB/XK*(DELT1-D1-DMIN)+D1+DMIN
      YMIX=XLAMB*(DELT1-D1-DMIN)
      YMIX2=YMIX*YMIX
      DO 420 J=JDL11,NM1
      DUDY=(UM(J+1)-UM(J-1))/(DY(J+1)+DY(J))
  420 VTRB(J)=YMIX2*ABS(DUDY)
      VTRB(N)=VTRB(NM1)
      VTRBO=VTRB(JDL11)
      JDL1=JDEL1-1
      DO 450 J=1,JDL1
      JTOP=JDL11-J
      IF(Y(JTOP)-YOMIN)460,430,430
  430 DUDY=(UM(JTOP+1)-UM(JTOP-1))/(DY(JTOP+1)+DY(JTOP))
      VTRBN=YMIX2*ABS(DUDY)
      IF(VTRBN-VTRBO)470,440,440
  440 VTRB(JTOP)=VTRBN
      VTRBO=VTRBN
  450 CONTINUE
      WRITE(IOT,90)
      STOP
C
C
C     THE MAXIMUM VALUE OF EDDY VISCOSITY IN THE OUTER REGION OF THE
C     TOTAL BOUNDARY LAYER IS CALCULATED BY INTERPOLATING BETWEEN
C     GRID POINTS FOR THE MAXIMUM VELOCITY GRADIENT.
C
  460 JTOP1=JTOP+1
      J1=JTOP-2
      J2=JTOP-1
      J3=JTOP
      J4=JTOP1
      J5=JTOP1+1
      J6=JTOP1+2
      DUDY1=(UM(J3)-UM(J1))/(DY(J3)+DY(J2))
      DUDY2=(UM(J4)-UM(J2))/(DY(J4)+DY(J3))
      DUDY3=(UM(J5)-UM(J3))/(DY(J5)+DY(J4))
      DUDY4=(UM(J6)-UM(J4))/(DY(J6)+DY(J5))
      DUDYM=GNINT (YOMIN,Y(J2),Y(J3),Y(J4),Y(J5),
     1 DUDY1,DUDY2,DUDY3,DUDY4)
      VTMM=YMIX2*ABS(DUDYM)
C
C
C     A SIMPLE COSINE FAIRING IS USED TO COMPLETE THE EDDY-VISCOSITY
C     PROFILE BETWEEN POINTS OF LOCAL MAXIMUM EDDY VISCOSITY IN EACH OF
C     THE JET REGION AND THE OVERALL BOUNDARY LAYER.
C
      YTOP1=YOMIN
      GO TO 480
  470 JTOP1=JTOP+1
      VTMM=VTRBO
      YTOP1=Y(JTOP1)
  480 EDAVE=(VTMM+VTMJ)/2.
      EDIFF=(VTMM-VTMJ)/2.
      YDIFF=YTOP1-YOUT
      DO 490 J=JOUT1,JTOP
      YY=Y(J)-YOUT
      ARG=(YY/YDIFF-0.5)*PI
  490 VTRB(J)=EDAVE+EDIFF*SIN(ARG)
C
C
C     INFORMATION ABOUT EACH OF THE JET AND TOTAL BOUNDARY LAYER IS
C     PRINTED, IF THIS OPTION HAS BEEN SPECIFIED BY THE USER.
C
      IF(JPRN)500,530,500
  500 WRITE(IOT,510)DELT2,UDEL2,YOUT,VTMJ
  510 FORMAT(/20X,'DELT2          UDEL2          YOUT          VTMJ'
     1 /16X,8E13.6)
      WRITE(IOT,520)DELT1,UDEL1,UTAU,VTMM,YTOP1
  520 FORMAT(/20X,'DELT1          UDEL1          UTAU          VTMM',
     1 '          YTOP1'/16X,8E13.6)
C
C
C******************************* STEP 2 ********************************
C
C******************* SOLVING THE MOMENTUM EQUATION *********************
C
C******************************* STEP 2 ********************************
C
C
C     THE DISTRIBUTION OF STREAMWISE VELOCITY IS CALCULATED BY SOLVING
C     A SYSTEM OF LINEAR ALGEBRAIC FINITE-DIFFERENCE EQUATIONS WHICH
C     APPROXIMATE THE DIFFERENTIAL EQUATION FOR THE CONSERVATION OF MOM
C     ENTUM IN AN INCOMPRESSIBLE TURBULENT BOUNDARY LAYER. CENTRAL DIF-
C     FERENCING IN THE Y-DIRECTION AND UPSTREAM DIFFERENCING IN THE
C     X-DIRECTION ARE USED TO EXPRESS PARTIAL DERIVATIVES.
C
C
C     THE WALL BOUNDARY CONDITION IS SET, I.E., U = 0 AT THE WALL.
C
  530 A(1)=0.
      B(1)=1.
      C(1)=0.
      D(1)=0.
C
C
C     THE FREE-STREAM BOUNDARY CONDITION IS SET, I.E., U = UE IN THE
C     FREE STREAM.
C
```

Figure A-1: A Documented Listing for Program Film (Page 8).

```
      A(N)=0.0
      B(N)=1.0
      C(N)=0.0
      D(N)=UFREE
C
C
C     THE REMAINING COEFFICIENTS IN THE TRIDIAGONALLY-BANDED SYSTEM OF
C     EQUATIONS ARE CALCULATED FROM THE VISCOSITIES COMPUTED ABOVE AND
C     THE MOST RECENT VELOCITY PROFILES.
C
      VTOTM=VSC(1)+VTRB(1)
      VTOT=VSC(2)+VTRB(2)
      DO 540 J=2,NM1
      VTOTP=VSC(J+1)+VTRB(J+1)
      PART1=2.*VM(J)*DY(J)-VTOTP+VTOTM
      A(J)=PART1+VTOT*(4.-PART2(J)-PART3(J))
      B(J)=-8.*VTOT-3.*UMLAS(J)*PART4(J)
      C(J)=-PART1+VTOT*(4.+PART2(J)+PART3(J))
      D(J)=UMLAS(J)*PART5(J)+PART6(J)/RO(J)
      VTOTM=VTOT
  540 VTOT=VTOTP
C
C
C     THE SECOND DERIVATIVE OF THE VELOCITY PROFILE IS SET TO ZERO
C     AT THE BOUNDARIES BETWEEN FINE AND COURSE GRIDS (I.E., MATCHING
C     SLOPES).
C
      DO 580 J=1,2
      GO TO (550,560),J
  550 NCC=NC1
      GO TO 570
  560 NCC=NC2
  570 A(NCC)=10.0
      B(NCC)=-11.0
      C(NCC)=1.0
      D(NCC)=0.0
  580 CONTINUE
C
C
C     SUBROUTINE TRIDI IS CALLED TO SOLVE THE SYSTEM OF LINEAR ALGEBRAIC
C     EQUATIONS WHICH GOVERN THE VELOCITY PROFILE.
C
      CALL TRIDI (A,B,C,D,UM,N,AP,AQ,AU)
C
C
C******************************** STEP 3 ********************************
C
C******************* SOLVING THE CONTINUITY EQUATION ********************
C
C******************************** STEP 3 ********************************
C
C
C     THE DISTRIBUTION OF TRANSVERSE VELOCITY IS CALCULATED BY SOLVING
C     THE CONTINUITY EQUATION WITH CENTRAL DIFFERENCING IN THE Y-DIR-
C     ECTION AND UPSTREAM DIFFERENCING IN THE X-DIRECTION, STARTING AT
C     THE WALL.
C
      DX4=4.*DX
      VM(1)=VWAL
      RROM=RAD*RO(1)
      DRRUM=3.*RROM*UM(1)-4.*RAD1*RO1(1)*UM1(1)+RAD2*RO2(1)*UM2(1)
      DO 590 J=2,N
      RROP=RLOC(J)*RO(J)
      DRRUP=3.*RROP*UM(J)-4.*RLOC1(J)*RO1(J)*UM1(J)+RLOC2(J)*RO2(J)*
     1 UM2(J)
      VM(J)=1./RRUP*(RROM*VM(J-1)-DY(J)/DX4*(DRRUM+DRRUP))
      DRRUM=DRRUP
  590 RROM=RROP
C
C
      RETURN
      END

C******************************** FLWTD ********************************
C******************************** FLWTD ********************************
C******************************** FLWTD ********************************
C
C
      SUBROUTINE FLWTD (UM,VM,TM,TM1,TM2,VSC,VTRB,ALM,ATRB,RO,PART2,
     1 PART3,PART4,PART7,RLOC,A,B,C,D,AP,AQ,AU,DY,DX,N,NC1,NC2,THOLD,
     2 Y,DELT1,TFREE,KOUNT,TATM)
C
C
C     THE PURPOSE OF THIS SUBROUTINE IS TO CALCULATE THE TEMPERATURE
C     PROFILE THROUGHOUT THE BOUNDARY LAYER AT A GIVEN STREAMWISE
C     STATION. THIS IS ACHIEVED BY
C
C          A) CALCULATING THE MOLECULAR AND EDDY THERMAL CONDUCTIVIT-
C             IES FROM THE CORRESPONDING MOLECULAR AND EDDY VISCOSITIES
C             AND A SUITABLE PRANDTL-NUMBER DISTRIBUTION, AND
C
C          B) SOLVING A SYSTEM OF LINEAR ALGEBRAIC FINITE-DIFFERENCE
C             EQUATIONS WHICH APPROXIMATE THE DIFFERENTIAL EQUATION
C             FOR THE CONSERVATION OF ENERGY IN AN INCOMPRESSIBLE TURB-
C             ULENT BOUNDARY LAYER, NEGLECTING PRESSURE WORK AND
C             VISCOUS DISSIPATION.
C
C
      DIMENSION UM(1),VM(1),TM(1),TM1(1),TM2(1),VSC(1),VTRB(1),ALM(1),
     1 ATRB(1),RO(1),PART2(1),PART3(1),PART4(1),PART7(1),RLOC(1),A(1),
     2 B(1),C(1),D(1),AP(1),AQ(1),AU(1),DY(1),THOLD(1),Y(1)
      COMMON IN,IOT,IF1,IF2,IF3,IF4,IF5,IF6,IF7,IF8,IF9,IF10,IRECU,IRECT
C
C
      NM1=N-1
      TNLIM=0.0001
C
C
C     THE EDDY AND MOLECULAR THERMAL CONDUCTIVITIES ARE CALCULATED FROM
C     THE EDDY AND MOLECULAR VISCOSITIES AND A SUITABLE PRANDTL-NUMBER
C     DISTRIBUTION.
C
      PRLAM=0.7
      DO 40 J=1,N
      YDELT=Y(J)/DELT1
      IF(YDELT-1.0)10,20,20
   10 PRTRB=1.75-1.25*YDELT
      GO TO 30
   20 PRTRB=0.50
   30 ALM(J)=VSC(J)/PRLAM
   40 ATRB(J)=VTRB(J)/PRTRB
C
C
C     THE WALL BOUNDARY CONDITION IS SET BELOW. FOR THE TIME BEING THE
C     WALL IS CONSIDERED TO BE ADIABATIC, I.E., DT/DY = 0. IF OTHER
C     THAN ADIABATIC CONDITIONS EXIST THEY WILL BE ACCOUNTED FOR LATER
C     IN SUBROUTINE QADD.
C
      A(1)=0.0
      B(1)=-1.0
      C(1)=1.0
      D(1)=0.0
C
C
C     THE FREE-STREAM BOUNDARY CONDITION IS SET, I.E., T = TE IN THE
C     FREE STREAM.
C
      A(N)=0.0
      B(N)=1.0
      C(N)=0.0
      D(N)=TFREE
C
C
C     THE REMAINING COEFFICIENTS IN THE TRIDIAGONALLY-BANDED SYSTEM OF
C     EQUATIONS ARE CALCULATED FROM THE THERMAL CONDUCTIVITIES COMPUTED
C     ABOVE AND THE MOST RECENT VELOCITY PROFILES.
C
      ATOTM=ALM(1)+ATRB(1)
      ATOT=ALM(2)+ATRB(2)
      DO 50 J=2,NM1
      ATOTP=ALM(J+1)+ATRB(J+1)
      PART1=2.*VM(J)*DY(J)-ATOTP+ATOTM
      A(J)=PART1+ATOT*(4.-PART2(J)-PART3(J))
      B(J)=-8.*ATOT-3.*UM(J)*PART4(J)
      C(J)=-PART1+ATOT*(4.+PART2(J)+PART3(J))
      D(J)=UM(J)*PART7(J)
      ATOTM=ATOT
   50 ATOT=ATOTP
C
C
C     THE SECOND DERIVATIVE OF THE TEMPERATURE PROFILE IS SET TO ZERO
C     AT THE BOUNDARIES BETWEEN FINE AND COURSE GRIDS (I.E., MATCHING
C     SLOPES).
C
      DO 90 J=1,2
      GO TO (60,70),J
   60 NCC=NC1
      GO TO 80
   70 NCC=NC2
   80 A(NCC)=10.0
      B(NCC)=-11.0
      C(NCC)=1.0
      D(NCC)=0.0
   90 CONTINUE
C
C
C     SUBROUTINE QADD IS CALLED TO PROVIDE OR EVALUATE ADDITIONAL HEAT
C     LOADS IN THE ENERGY BALANCE AT THE WALL. IF QWALL IS ZERO AFTER
C     RETURNING  FROM QADD THEN THE WALL IS ADIABATIC AND THE PREVIOUS
C     ASSUMPTION APPLIES. IF QWALL IS NOT ZERO THEN D(1) IS ALTERED
C     IN ACCORDANCE WITH Q = K * DT/DY. SINCE MANY OF THESE HEAT LOADS
C     DEPEND ON THE WALL TEMPERATURE AN ITERATION IS PERFORMED TO ACH-
C     IEVE CONSISTENCY.
C
      QWALL=0.0
      CALL QADD (TM,QWALL,N,KOUNT,TATM)
      IF(QWALL)110,100,110
  100 CALL TRIDI (A,B,C,D,TM,N,AP,AQ,AU)
      RETURN
  110 DO 150 JJ=1,10
      D(1)=QWALL*DY(2)/THCON(TM(1))
      DO 120 J=1,N
  120 THOLD(J)=TM(J)
      CALL TRIDI (A,B,C,D,TM,N,AP,AQ,AU)
      FNRMT=0.0
      DO 130 J=1,N
  130 FNRMT=FNRMT+ABS(TM(J)-THOLD(J))/TM(J)
      FNRMT=FNRMT/N
      IF(FNRMT-TNLIM)160,160,140
  140 CALL QADD (TM,QWALL,N,KOUNT,TATM)
  150 CONTINUE
C
C
  160 RETURN
      END

C******************************** FTIDY ********************************
C******************************** FTIDY ********************************
C******************************** FTIDY ********************************
C
C
      SUBROUTINE FTIDY (UM,UM1,TM,TM1,VM,VM1,Y,NDIM,N)
C
C
C     THE PURPOSE OF THIS SUBROUTINE IS TO STORE INFORMATION ABOUT THE
C     OUTFLOW BOUNDARY CONDITIONS AFTER THE FLOW FIELD HAS BEEN COMP-
C     UTED. THIS INFORMATION IS STORED IN DISK FILES FOR FUTURE REFER-
C     ENCE.
C
C
      DIMENSION UM(1),UM1(1),TM(1),TM1(1),VM(1),VM1(1),Y(1)
      COMMON IN,IOT,IF1,IF2,IF3,IF4,IF5,IF6,IF7,IF8,IF9,IF10,IRECU,IRECT
      WRITE(IF3'1)(UM(J),J=1,NDIM)
      WRITE(IF4'1)(UM1(J),J=1,NDIM)
      WRITE(IF5'1)(VM(J),J=1,NDIM)
      WRITE(IF6'1)(VM1(J),J=1,NDIM)
      WRITE(IF7'1)(TM(J),J=1,NDIM)
      WRITE(IF8'1)(TM1(J),J=1,NDIM)
      WRITE(IF9'1)(Y(J),J=1,NDIM)
      WRITE(IF10'1)N
C
C
      RETURN
      END
```

Figure A-1: A Documented Listing for Program Film (Page 9).

```
C********************************* FLINK **********************************
C********************************* FLINK **********************************
C********************************* FLINK **********************************
C
C
      SUBROUTINE FLINK (Y,YOLD,X,XOLD,N,NOLD,N2,NFILE)
C
C
C     THE PURPOSE OF THIS SUBROUTINE IS TO COMPUTE AN INFLOW BOUNDARY
C     CONDITION FOR THE PRESENT RUN BASED ON THE OUTFLOW BOUNDARY COND-
C     ITION FROM THE LAST RUN TO BE EXECUTED. THIS IS ACHIEVED BY
C
C           A) READING IN AN OUTFLOW BOUNDARY PROFILE, XOLD AS A FUNC-
C              TION OF YOLD, STORED IN A DISK FILE AT THE CONCLUSION OF
C              THE LAST RUN TO BE EXECUTED, AND
C
C           B) INTERPOLATING BETWEEN GRID POINTS IN THE OUTFLOW PROFILE
C              TO ARRIVE AT AN INFLOW PROFILE, X AS A FUNCTION OF Y,
C              SUITABLE FOR THE PRESENT FLOW FIELD CALCULATIONS.
C
C
      DIMENSION Y(1),YOLD(1),X(1),XOLD(1)
C
C
C     THE OUTFLOW PROFILE FROM THE LAST EXECUTION IS READ IN BELOW.
C
      READ(NFILE'1)(XOLD(J),J=1,NOLD)
C
C
C     INTERPOLATION BETWEEN GRID POINTS OF THE OUTFLOW PROFILE TO
C     ARRIVE AT A SUITABLE INFLOW PROFILE IS ACCOMPLISHED BELOW.
C
      K1=1
      N21=N2+1
      X(N2)=XOLD(1)
      DO 90 J=N21,N
      DO 10 K=K1,NOLD
      IF(YOLD(K)-Y(J))10,10,40
   10 CONTINUE
C
C
C     IF THE REQUIRED INFLOW GRID IS OF GREATER DIMENSION THAN THE
C     AVAILABLE OUTFLOW GRID, THEN THE VALUE AT ANY POINT IN THE INFLOW
C     GRID FOR WHICH THERE IS NO CORRESPONDING POINT IN THE OUTFLOW
C     GRID WILL BE SET TO THAT OF THE LAST POINT IN THE OUTFLOW GRID.
C
   20 DO 30 JJ=J,N
   30 X(JJ)=XOLD(NOLD)
      RETURN
C
C
C     IF THIS IS NOT THE CASE THEN AN INTERPOLATION IS PERFORMED
C     USING A THIRD-ORDER POLYNOMIAL CURVE FIT TO VALUES AT NEIGHBOUR-
C     ING GRID POINTS.
C
   40 K1=K-2
      K2=K-1
      K3=K
      K4=K+1
      IF(K1-1)50,60,60
   50 K1=1
      K2=2
      K3=3
      K4=4
      GO TO 80
   60 IF(K3-NOLD)80,70,70
   70 K1=NOLD-3
      K2=NOLD-2
      K3=NOLD-1
      K4=NOLD
   80 X(J)=GNINT (Y(J),YOLD(K1),YOLD(K2),YOLD(K3),YOLD(K4),
     1 XOLD(K1),XOLD(K2),XOLD(K3),XOLD(K4))
   90 CONTINUE
C
C
      RETURN
      END

C********************************* QADD ***********************************
C********************************* QADD ***********************************
C********************************* QADD ***********************************
C
C
      SUBROUTINE QADD (TM,QWALL,N,KOUNT,TATM)
C
C
C     THE PURPOSE OF THIS SUBROUTINE IS TO ALLOW THE USER THE OPPORTUN-
C     ITY TO INCLUDE EXTRA TERMS IN THE HEAT BALANCE AT THE WALL. COM-
C     MON EXAMPLES ARE RADIATIVE HEAT TRANSFER AND CONVECTION ON THE
C     OUTSIDE OF THE WALL. IN ANY EVENT, THE TERM QWALL MUST BE COMPUTED
C     SO THAT IT IS THE HEAT  T A K E N  F R O M  THE WALL IN UNITS OF
C     BTU/SEC-FT-FT.
C
C     AS IT STANDS THIS SUBROUTINE IS SET UP TO INCLUDE
C
C           A) RADIATIVE HEAT TRANSFER FROM A HOT GAS TO THE WALL,
C
C           B) RADIATIVE HEAT TRANSFER FROM A HOT BODY TO THE WALL,
C              AND
C
C           C) RADIATIVE HEAT TRANSFER FROM THE WALL TO A COLD BODY.
C
C     THE TEMPERATURES OF THE WALL, COLD BODY, HOT BODY AND HOT GAS
C     ARE TW, TC, TH AND TG, RESPECTIVELY. THE EMISSIVITIES ARE EW,
C     EC, EH AND EG, RESPECTIVELY. THE SHAPE FACTOR BETWEEN THE COLD
C     BODY AND THE WALL IS SHPWC, THAT BETWEEN THE HOT BODY AND THE
C     WALL IS SHPHW, THAT BETWEEN THE GAS AND THE WALL IS UNITY. FOR
C     THE PRESENT CASE RADIATIVE HEAT TRANSFER BETWEEN NEIGHBOURING
C     PORTIONS OF THE WALL IS NEGLECTED.
C
C
      COMMON IN,IOT,IF1,IF2,IF3,IF4,IF5,IF6,IF7,IF8,IF9,IF10,IRECU,IRECT
      DIMENSION TM(1),SHPHW(20),SHPWC(20)
      DATA SHPHW(1),SHPHW(2),SHPHW(3),SHPHW(4),SHPHW(5),SHPHW(6),
     1SHPHW(7),SHPHW(8),SHPHW(9),SHPHW(10),SHPHW(11)
     2/.500,.463,.430,.390,.369,.342,.316,.293,.271,.251,.232/
      DATA SHPWC(1),SHPWC(2),SHPWC(3),SHPWC(4),SHPWC(5),SHPWC(6),
     1SHPWC(7),SHPWC(8),SHPWC(9),SHPWC(10),SHPWC(11)
     2/.000,.048,.051,.055,.058,.062,.066,.071,.076,.081,.087/
C
C
      BOLTZ=4.761E-13
      TH=571.5
      TC=TATM
      TW=TM(1)
      TG=TM(N)
      EH=1.0
      EC=1.0
      EW=0.95
      EG=0.05
      TH4=TH*TH*TH*TH
      TC4=TC*TC*TC*TC
      TW4=TW*TW*TW*TW
      TG4=TG*TG*TG*TG
      QWALL=BOLTZ*(-EH*EW*SHPHW(KOUNT)*(TH4-TW4)
     1 +EW*EC*SHPWC(KOUNT)*(TW4-TC4)
     2 -EG*EW*(TG4-TW4))
C
C
      RETURN
      END
C********************************* BLINT **********************************
C********************************* BLINT **********************************
C********************************* BLINT **********************************
C
C
      SUBROUTINE BLINT (NC,DY,Y,RADD,UM,ROE,DISP,MOM,M,COORD,ALPHA,
     1 SHIFT)
C
C
C     THE PURPOSE OF THIS SUBROUTINE IS TO CALCULATE THE DISPLACEMENT
C     AND MOMENTUM DEFICIT THICKNESSES FOR AN ARBITRARY BOUNDARY LAYER
C     BY NUMERICALLY INTEGRATING ITS VELOCITY PROFILE. THESE PARAMETERS
C     ARE USED TO COMPUTE THE VELOCITY PROFILE SHAPE FACTOR.
C
C
      INTEGER COORD
      REAL MOM,INTD,INTM
      DIMENSION UM(1),ROE(1),Y(1),DY(1),NC(1)
      COMMON IN,IOT,IF1,IF2,IF3,IF4,IF5,IF6,IF7,IF8,IF9,IF10,IRECU,IRECT
C
C
C     INITIALIZATION SEGMENT
C
      RAD=RADD-SHIFT*COS(ALPHA)
      CORAD=COS(ALPHA)/RAD
      FACT=1.
C
C     THE NUMBER OF GRID ZONES IN THE BOUNDARY LAYER, JEE1, IS DETER-
C     MINED BY EXAMINING ARRAY NC.
C
      JEE=2
      DO 20 J=3,4
      IF(NC(J))30,30,10
   10 JEE=J
   20 CONTINUE
   30 JEE1=JEE-1
C
      JDEL=NC(JEE)
      J1=NC(1)
      ROEE=ROE(JDEL)
      UEE=UM(JDEL)
      ROEUE=ROEE*UEE
      TOTD=0.0
      TOTM=0.0
C
C
C     INTEGRATION TO FIND THE DISPLACEMENT AND MOMENTUM DEFICIT
C     THICKNESSES IS DONE BELOW. EACH GRID ZONE IS INTEGRATED SEPARATE-
C     LY AS FOLLOWS. IF AN EVEN NUMBER OF INTERVALS IS PRESENT IN A GRID
C     ZONE SIMPSON'S RULE IS USED TO INTEGRATE FROM ISTRT TO ISTP. IF AN
C     ODD NUMBER OF INTERVALS IS PRESENT SIMPSON'S RULE IS USED TO INT-
C     EGRATE FROM ISTRT TO IS1. THE REMAINING INTERVAL IS INTEGRATED BY
C     THE TRAPAZOID RULE.
C
C
      DO 230 JSEC=1,JEE1
      ISTRT=NC(JSEC)
      ISTP=NC(JSEC+1)
      DYY=DY(ISTP)
      IST1=ISTRT+1
      IS1 =ISTP-1
      ROU=ROE(ISTRT)*UM(ISTRT)
      INTD=ROEUE-ROU
      INTM=ROU*(UEE-UM(ISTRT))
C
C     IF THE COORDINATE SYSTEM IS AXISYMMETRIC (COORD POSITIVE) A
C     GEOMETRIC FACTOR IS INCLUDED IN THE INTEGRATION. THIS FACTOR IS
C     UNITY FOR PLANE FLOWS.
C
      IF(COORD)50,50,40
C
C     COORD POSITIVE
C
   40 YY=Y(ISTRT)-SHIFT
      FACT=1.-YY*CORAD
      INTD=INTD*FACT
      INTM=INTM*FACT
C
C     COORD NOT POSITIVE
C
   50 IF(ISTP-ISTRT-1)60,60,70
   60 JLIM=IST1
      GO TO 100
C
C
C     THE INTEGRATION LIMIT FOR A PARTICULAR GRID ZONE IS SET BY DETER-
C     MINING WHETHER AN ODD OR EVEN NUMBER OF INTERVALS IS PRESENT.
C
   70 JIND=-1
      INDEX=ISTP-ISTRT
      NUM=INDEX-2*(INDEX/2)
```

Figure A-1: A Documented Listing for Program Film (Page 10).

```
      IF(NUM)90,90,80
   80 JLIM=IS1
      GO TO 100
   90 JLIM=ISTP
C
C
C     THE INTEGRATION IS PERFORMED FOR A PARTICULAR GRID ZONE BELOW.
C
  100 DO 160 J=ISTI,JLIM
      IF(J-JLIM)120,110,110
  110 MULT=1
      GO TO 130
  120 JIND=-JIND
      MULT=3+JIND
  130 ROU=ROE(J)*UM(J)
      TERMA=ROEUE-ROU
      TERMB=ROU*(UEE-UM(J))
      IF(COORD)150,150,140
  140 YY=Y(J)-SHIFT
      FACT=1.-YY*CORAD
  150 INTD=INTD+FACT*TERMA*MULT
      INTM=INTM+FACT*TERMB*MULT
  160 CONTINUE
      IF(ISTP-ISTRT-1)170,170,180
  170 INTD=INTD/2.*DYY
      INTM=INTM/2.*DYY
      GO TO 220
  180 INTD=INTD*DYY/3.
      INTM=INTM*DYY/3.
C
C     IN THE EVENT THAT THE NUMBER OF INTEGRATION INTERVALS IS ODD THE
C     INTERVAL LEFT OVER FROM THE INTEGRATION BY SIMPSON'S RULE IS INT-
C     EGRATED BY THE TRAPAZOID RULE BELOW.
C
      IF(NUM)220,220,190
  190 HOLDA=TERMA*FACT
      HOLDB=TERMB*FACT
      ROU=ROE(ISTP)*UM(ISTP)
      TERMA=ROEUE-ROU
      TERMB=ROU*(UEE-UM(ISTP))
      IF(COORD)210,210,200
  200 YY=Y(ISTP)-SHIFT
      FACT=1.-YY*CORAD
      TERMA=TERMA*FACT
      TERMB=TERMB*FACT
  210 INTD=INTD+(HOLDA+TERMA)/2.*DYY
      INTM=INTM+(HOLDB+TERMB)/2.*DYY
  220 TOTD=TOTD+INTD
      TOTM=TOTM+INTM
  230 CONTINUE
C
C
C     THE INTEGRATED AREAS ARE MULTIPLIED BY APPROPRIATE FACTORS BELOW.
C     IN THE CASE OF PLANE FLOW THESE RESULTS ARE THE DISPLACEMENT AND
C     MOMENTUM DEFICIT THICKNESSES, RESPECTIVELY. IN THE CASE OF AXISYM-
C     METRIC FLOWS THESE RESULTS ARE THE CONSTANT TERMS IN QUADRATIC
C     EQUATIONS WHICH MUST BE SOLVED FOR THE DESIRED THICKNESSES.
C
      TOTD=TOTD/ROEUE
      TOTM=TOTM/ROEUE/UEE
C
      IF(COORD)240,240,250
C
C     COORD NOT POSITIVE
C
  240 DISP=TOTD
      MOM=TOTM
      GO TO 300
C
C     COORD POSITIVE
C
  250 AA=-CORAD/2.
      RADIC=1.+4.*AA*TOTD
      IF(RADIC)260,280,280
  260 WRITE(IOT,270)
  270 FORMAT(///10X,'***  FATAL ERROR IN SUBROUTINE BLINT.'/15X,
     1 'NEGATIVE RADICAL.'/15X,'JOB ABORTED.')
      STOP
  280 DISP=(-1.+SQRT(RADIC))/2./AA
      RADIC=1.+4.*AA*TOTM
      IF(RADIC)260,290,290
  290 MOM=(-1.+SQRT(RADIC))/2./AA
C
C     THE VELOCITY PROFILE SHAPE FACTOR IS COMPUTED BELOW.
C
  300 H=DISP/MOM
C
C
      RETURN
      END

C******************************** WLAW ********************************
C******************************** WLAW ********************************
C******************************** WLAW ********************************
C
C
      SUBROUTINE WLAW (A,B,C,D,X2)
C
C
C     THE PURPOSE OF THIS SUBROUTINE IS TO SOLVE THE EQUATION
C     A/X = B * LOG(C*X) + D FOR X WHERE A,B,C AND D ARE KNOWN QUANT-
C     ITIES SUPPLIED TO THE SUBROUTINE IN THE ARGUMENT LIST. AN INIT-
C     IAL GUESS AT THE ROOT IS MADE AND TWENTY NEWTON-RAPHSON ITERATIONS
C     ARE PERFORMED. IF CONVERGENCE IS NOT ACHIEVED THE INITIAL GUESS
C     IS MADE SMALLER AND THE PROCEDURE REPEATED. AFTER TEN ATTEMPTS AT
C     ALTERING THE INITIAL GUESS HAVE BEEN MADE AND CONVERGENCE HAS NOT
C     BEEN ACHIEVED THE PROCESS IS TERMINATED.
C
C
      COMMON IN,IOT,IF1,IF2,IF3,IF4,IF5,IF6,IF7,IF8,IF9,IF10,IRECU,IRECT
      F(X)=A/X-B*ALOG(C*X)-D
C
C
C     THE GUESS IS ALTERED UP TO TEN TIMES.
C
      GUESS=1.
      DO 60 JTIME=1,10
      GUESS=GUESS*0.1
      DX=GUESS*0.1
      X1=GUESS
C
C
C     UP TO TWENTY NEWTON-RAPHSON ITERATIONS ARE PERMITTED FOR EACH
C     GUESS.
C
      DO 20 J=1,20
      XPLUS=X1+DX
      XMIN=X1-DX
      FPLUS=F(XPLUS)
      FAVE=F(X1)
      FMIN=F(XMIN)
      X2=X1-FAVE*2.*DX/(FPLUS-FMIN)
      IF(ABS(X2-X1)/X2-0.0001)30,30,10
   10 X1=X2
   20 CONTINUE
      GO TO 60
   30 IF(X2)60,60,40
   40 IF(A-X2)60,60,50
   50 RETURN
   60 CONTINUE
      WRITE(IOT,70)
   70 FORMAT(///10X,'***  FATAL ERROR IN SUBROUTINE WLAW.'/15X,
     1 'CONVERGENCE CANNOT BE ACHIEVED.'/15X,'JOB ABORTED.')
C
C
      STOP
      END

C******************************** TRIDI *******************************
C******************************** TRIDI *******************************
C******************************** TRIDI *******************************
C
C
      SUBROUTINE TRIDI (A,B,C,D,X,N,AP,AQ,AU)
C
C
C     THE PURPOSE OF THIS SUBROUTINE IS TO SOLVE A SYSTEM OF LINEAR
C     ALGEBRAIC EQUATIONS WHICH IS IN TRIDIAGONALLY-BANDED FORM.
C
C
      DIMENSION A(1),B(1),C(1),D(1),X(1),AP(1),AQ(1),AU(1)
C
C
      JA1=2
      JB1=N-1
      JA=JA1-1
      JB=JB1+1
      AP(JA)=B(JA)
      AQ(JA)=-C(JA)/B(JA)
      DO 10 I=JA1,JB1
      AP(I)=A(I)*AQ(I-1)+B(I)
   10 AQ(I)=-C(I)/AP(I)
      AP(JB)=A(JB)*AQ(JB1)+B(JB)
      AU(JA)=D(JA)/B(JA)
      DO 20 I=JA1,JB
   20 AU(I)=(D(I)-A(I)*AU(I-1))/AP(I)
      X(JB)=AU(JB)
      DO 30 II=JA1,JB
      I=JB-II+JA
   30 X(I)=AQ(I)*X(I+1)+AU(I)
C
C
      RETURN
      END

C******************************** GNINT *******************************
C******************************** GNINT *******************************
C******************************** GNINT *******************************
C
C
      FUNCTION GNINT (XINT,X1,X2,X3,X4,F1,F2,F3,F4)
C
C
C     THE PURPOSE OF THIS FUNCTION IS TO FIT A THIRD-ORDER POLYNOMIAL
C     TO THE DATA POINTS (X1,F1), (X2,F2), (X3,F3) AND (X4,F4) AND TO
C     RETURN THE VALUE OF THE FUNCTION, GNINT, FOR AN ARGUMENT OF XINT.
C
C
C     THE COEFFICIENTS OF THE POLYNOMIAL ARE CALCULATED BELOW.
C
      A1=F1
      A2=(F2-A1)/(X2-X1)
      A3=(F3-A1-A2*(X3-X1))/(X3-X1)/(X3-X2)
      A4=(F4-A1-A2*(X4-X1)-A3*(X4-X1)*(X4-X2))/(X4-X1)/(X4-X2)/(X4-X3)
C
C
C     THE FUNCTION IS EVALUATED FOR AN ARGUMENT OF XINT BELOW.
C
      GNINT=A1+A2*(XINT-X1)+A3*(XINT-X1)*(XINT-X2)+A4*(XINT-X1)*
     1 (XINT-X2)*(XINT-X3)
C
C
      RETURN
      END

C******************************** MEW *********************************
C******************************** MEW *********************************
C******************************** MEW *********************************
C
C
      REAL FUNCTION MEW(T)
C
C
C     THE PURPOSE OF THIS FUNCTION IS TO CALCULATE THE DYNAMIC
C     VISCOSITY OF AIR, MEW (LBM/SEC-FT), WHICH CORRESPONDS TO THE
C     TEMPERATURE, T ('R), SUPPLIED AS THE ARGUMENT. THIS IS DONE BY
C     LINEAR INTERPOLATION IN A TABLE OF TEMPERATURES AND CORRESP-
C     ONDING VISCOSITIES.
C
C
```

Figure A-1: A Documented Listing for Program Film (Page 11).

```
      DIMENSION XMEW(11)
      COMMON IN,IOT,IF1,IF2,IF3,IF4,IF5,IF6,IF7,IF8,IF9,IF10,IRECU,IRECT
      DATA XMEW(1),XMEW(2),XMEW(3),XMEW(4),XMEW(5),XMEW(6),XMEW(7),
     1 XMEW(8),XMEW(9),XMEW(10),XMEW(11)
     2 /1.11E-5,1.285E-5,1.44E-5,1.61E-5,1.75E-5,1.89E-5,2.E-5,2.14E-5,
     3 2.25E-5,2.36E-5,2.47E-5/
C
C
C     A CHECK IS MADE TO ENSURE THAT THE SUPPLIED TEMPERATURE FALLS
C     WITHIN THE RANGE 460 - 1460 'R. IF THIS CONDITION IS NOT MET AN
C     ERROR MESSAGE IS PRINTED AND THE JOB IS ABORTED.
C
      IF(T-460.)20,10,10
   10 IF(T-1460.)40,40,20
   20 WRITE(IOT,30)
   30 FORMAT(///10X,'*** FATAL ERROR IN FUNCTION MEW.'/15X,'THE SUPPLIE
     1D TEMPERATURE IS OUT OF RANGE.'/15X,'JOB ABORTED.')
      STOP
C
C
C     THE LINEAR INTERPOLATION IS DONE BELOW.
C
   40 TT=T-460.
      NT=TT/100.
      NTT=NT*100
      NDIM=NT+1
      MEW=XMEW(NDIM)+(TT-NTT)/100.*(XMEW(NDIM+1)-XMEW(NDIM))
C
C
      RETURN
      END

C******************************* THCON ********************************
C******************************* THCON ********************************
C******************************* THCON ********************************
C
C
      FUNCTION THCON(T)
C
C
C     THE PURPOSE OF THIS FUNCTION IS TO CALCULATE THE THERMAL COND-
C     UCTIVITY OF AIR, THCON (BTU/SEC-FT-'R), WHICH CORRESPONDS TO THE
C     TEMPERATURE, T ('R), SUPPLIED AS THE ARGUMENT. THIS IS DONE BY
C     LINEAR INTERPOLATION IN A TABLE OF TEMPERATURES AND CORRESPONDING
C     THERMAL CONDUCTIVITIES.
C
C
      DIMENSION C(11)
      COMMON IN,IOT,IF1,IF2,IF3,IF4,IF5,IF6,IF7,IF8,IF9,IF10,IRECU,IRECT
      DATA C(1),C(2),C(3),C(4),C(5),C(6),C(7),C(8),C(9),C(10),C(11)
     1 /3.694E-6,4.278E-6,4.833E-6,5.361E-6,5.889E-6,6.417E-6,6.944E-6,
     2 7.444E-6,7.944E-6,8.417E-6,8.861E-6/
C
C
C     A CHECK IS MADE TO ENSURE THAT THE SUPPLIED TEMPERATURE FALLS
C     WITHIN THE RANGE 460 - 1460 'R. IF THIS CONDITION IS NOT MET AN
C     ERROR MESSAGE IS PRINTED AND THE JOB IS ABORTED.
C
      IF(T-460.)20,10,10
   10 IF(T-1460.)40,40,20
   20 WRITE(IOT,30)
   30 FORMAT(///10X,'*** FATAL ERROR IN FUNCTION THCON.'/15X,
     1 'THE SUPPLIED TEMPERATURE IS OUT OF RANGE.'/15X,'JOB ABORTED.')
      STOP
C
C
C     THE LINEAR INTERPOLATION IS DONE BELOW.
C
   40 TT=T-460.
      NT=TT/100.
      NTT=NT*100
      NDIM=NT+1
      THCON=C(NDIM)+(TT-NTT)/100.*(C(NDIM+1)-C(NDIM))
C
C
      RETURN
      END

C******************************* OTPT1 ********************************
C******************************* OTPT1 ********************************
C******************************* OTPT1 ********************************
C
C
      SUBROUTINE OTPT1 (D2,DX,N,VECTR)
C
C
C     THE PURPOSE OF THIS SUBROUTINE IS TO PRINT N ELEMENTS OF ARRAY
C     VECTR, WHICH ARE FUNCTIONS OF X (D2 AND DX), SIX TO A LINE.
C
C
      DIMENSION VECTR(1)
      COMMON IN,IOT,IF1,IF2,IF3,IF4,IF5,IF6,IF7,IF8,IF9,IF10,IRECU,IRECT
C
C
      WRITE(IOT,10)
   10 FORMAT(1X)
      X=D2*12.
      JB=1
      NUM=N/6+1.001
      DO 50 J=1,NUM
      JC=JB+5
      IF(JC-N)30,30,20
   20 JC=N
   30 WRITE(IOT,40)X,(VECTR(JA),JA=JB,JC)
   40 FORMAT( 11X,F8.3,2X,'*',2X,6(E14.7,2X))
      X=X+72.*DX
      JB=JB+6
   50 CONTINUE
C
C
      RETURN
      END

C******************************* OTPT2 ********************************
C******************************* OTPT2 ********************************
C******************************* OTPT2 ********************************
C
C
      SUBROUTINE OTPT2 (N,Y,VECTR)
C
C
C     THE PURPOSE OF THIS SUBROUTINE IS TO PRINT N ELEMENTS OF ARRAY
C     VECTR, WHICH ARE FUNCTIONS OF Y, TEN TO A LINE.
C
C
      DIMENSION Y(1),VECTR(1)
      COMMON IN,IOT,IF1,IF2,IF3,IF4,IF5,IF6,IF7,IF8,IF9,IF10,IRECU,IRECT
C
C
      WRITE(IOT,10)
   10 FORMAT(1X)
      JB=1
      NUM=N/10.+1.001
      DO 50 J=1,NUM
      JC=JB+9
      IF(JC-N)30,30,20
   20 JC=N
   30 YY=Y(JB)*12.
      WRITE(IOT,40)YY,(VECTR(JA),JA=JB,JC)
   40 FORMAT(1X,F7.4,'  *  ',10E12.5)
      JB=JB+10
   50 CONTINUE
C
C
      RETURN
      END
```

JOB CONTROL LANGUAGE FOR CREATING FILES

```
//GO.FT11F001 DD DSNAME=L357421.ME02.UVEL,UNIT=3330-1,VOL=SER=MRDC64,
//               DISP=(NEW,CATLG,DELETE),SPACE=(8000,(50,000)),
//               DCB=(RECFM=F,BLKSIZE=8000)
//GO.FT12F001 DD DSNAME=L357421.ME02.TEMP,UNIT=3330-1,VOL=SER=MRDC64,
//               DISP=(NEW,CATLG,DELETE),SPACE=(8000,(50,000)),
//               DCB=(RECFM=F,BLKSIZE=8000)
//GO.FT13F001 DD DSNAME=L357421.ME02.UUM1,UNIT=3330-1,VOL=SER=MRDC64,
//               DISP=(NEW,CATLG,DELETE),SPACE=(8000,(1,000)),
//               DCB=(RECFM=F,BLKSIZE=8000)
//GO.FT14F001 DD DSNAME=L357421.ME02.UUM2,UNIT=3330-1,VOL=SER=MRDC64,
//               DISP=(NEW,CATLG,DELETE),SPACE=(8000,(1,000)),
//               DCB=(RECFM=F,BLKSIZE=8000)
//GO.FT15F001 DD DSNAME=L357421.ME02.VVM1,UNIT=3330-1,VOL=SER=MRDC64,
//               DISP=(NEW,CATLG,DELETE),SPACE=(8000,(1,000)),
//               DCB=(RECFM=F,BLKSIZE=8000)
//GO.FT16F001 DD DSNAME=L357421.ME02.VVM2,UNIT=3330-1,VOL=SER=MRDC64,
//               DISP=(NEW,CATLG,DELETE),SPACE=(8000,(1,000)),
//               DCB=(RECFM=F,BLKSIZE=8000)
//GO.FT17F001 DD DSNAME=L357421.ME02.TTM1,UNIT=3330-1,VOL=SER=MRDC64,
//               DISP=(NEW,CATLG,DELETE),SPACE=(8000,(1,000)),
//               DCB=(RECFM=F,BLKSIZE=8000)
//GO.FT18F001 DD DSNAME=L357421.ME02.TTM2,UNIT=3330-1,VOL=SER=MRDC64,
//               DISP=(NEW,CATLG,DELETE),SPACE=(8000,(1,000)),
//               DCB=(RECFM=F,BLKSIZE=8000)
//GO.FT19F001 DD DSNAME=L357421.ME02.YYY,UNIT=3330-1,VOL=SER=MRDC64,
//               DISP=(NEW,CATLG,DELETE),SPACE=(8000,(1,000)),
//               DCB=(RECFM=F,BLKSIZE=8000)
//GO.FT20F001 DD DSNAME=L357421.ME02.PARA,UNIT=3330-1,VOL=SER=MRDC64,
//               DISP=(NEW,CATLG,DELETE),SPACE=(8000,(1,000)),
//               DCB=(RECFM=F,BLKSIZE=8000)
```

JOB CONTROL LANGUAGE FOR REFERENCING EXISTING FILES.

```
//GO.FT11F001 DD DSNAME=L357421.ME02.UVEL,DISP=OLD
//GO.FT12F001 DD DSNAME=L357421.ME02.TEMP,DISP=OLD
//GO.FT13F001 DD DSNAME=L357421.ME02.UUM1,DISP=OLD
//GO.FT14F001 DD DSNAME=L357421.ME02.UUM2,DISP=OLD
//GO.FT15F001 DD DSNAME=L357421.ME02.VVM1,DISP=OLD
//GO.FT16F001 DD DSNAME=L357421.ME02.VVM2,DISP=OLD
//GO.FT17F001 DD DSNAME=L357421.ME02.TTM1,DISP=OLD
//GO.FT18F001 DD DSNAME=L357421.ME02.TTM2,DISP=OLD
//GO.FT19F001 DD DSNAME=L357421.ME02.YYY,DISP=OLD
//GO.FT20F001 DD DSNAME=L357421.ME02.PARA,DISP=OLD
//GO.SYSIN DD *
 •
 •
 •
DATA
 •
 •
 •
/*
```

Figure A-1: A Documented Listing for Program Film (Page 12).

APPENDIX B

A Guide to the Use of Program FILM

APPENDIX B

A Guide to the Use of Program FILM

The purpose of this appendix is to acquaint the user with the Fortran program so that he is able to perform a successful execution. Details are outlined under the following headings;

i) Setting Up a Data Deck for Program FILM, and

ii) Sample Data Deck and Results.

Setting Up a Data Deck for Program FILM

1.0	General Information	format
DATA:	JPRN, COORD, JSTRT, JSLOT, JSTOT, JHEAT	6I2

JPRN = 0 to omit printout of results at key points in the computations. Otherwise, a printout will be produced.

COORD = 0 for axisymmetric flow. Otherwise, plane flow is assumed.

JSTRT = 0 if data describing the main-stream conditions at inflow are to be specified by the user. Otherwise, output boundary conditions from the last run to be executed will be fetched from the disk and used to describe the main stream in the present run.

JSLOT is the slot number as identified by the user. It is present only for recording purposes.

JSTOT is the total number of slots in the application being investigated. It is present only for recording purposes.

JHEAT = 0 for cases where it is not necessary to solve the energy equation. In these cases the temperature profile that is specified at the inflow boundary is assumed to exist at all streamwise stations in the flow field.

DATA:	D1, D2, DX, DYY, XL, XH, DW, DWIN	8F10.6

D1 is the slot width (inches).

D2 is the length of the injection slot (inches).

format

DX is the incremental distance between stations in the streamwise direction (inches).

DYY is the incremental distance between stations in the transverse direction of the finest grid zone (inches).

XL is the overall length of the surface over which the flow is to be computed. It is measured from the entrance of the injection slot to the downstream end of the grid (inches).

XH is the height of the grid network (inches), measured from the duct wall.

DW is the duct wall thickness (inches).

DWIN is the slot lip thickness (inches).

DATA: PATM, TATM, RGAS, TWMAX 4F12.6

PATM is ambient pressure (psia) on the exterior of the duct.

TATM is ambient temperature (°R) on the exterior of the duct.

RGAS is the gas constant for both injected and main streams ($ft\text{-}lb_f/lb_m$ - °R).

TWMAX is the maximum allowable wall temperature (°R) that the duct can assume. The run will terminate if the wall exceeds this temperature.

2.0 Input of Data Pertaining to Streamwise Boundary Conditions

2.1 Duct Radius and Wall Slope

DATA: JRADL I2

JRADL is a flag to assist in setting up streamwise distributions of duct radius and wall slope. JRADL = 0 implies Case 1. Otherwise, Case 2 is assumed. Note that for plane flow this information is required only for recording purposes.

format

Case 1 (JRADL = 0)

DATA: RADUP, RDIUS(1), ...RDIUS(J), ...RDIUS(M) — 8F10.6 per card

RADUP — is the duct radius (inches) one station upstream of the point of injection.

RDIUS(J) — is the duct radius (inches) at streamwise station J in the grid network.

DATA: ALPHU, ALPHA(1), ...ALPHA(J), ...ALPHA(M) — 8F10.6 per card

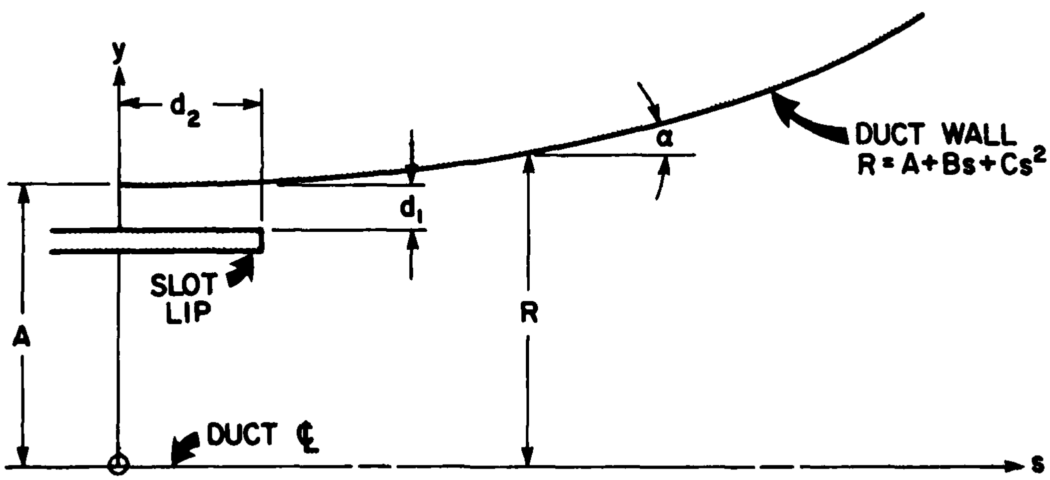
ALPHU — is the duct wall slope (radians) one station upstream of the point of injection.

ALPHA(J) — is the duct wall slope (radians) at streamwise station J in the grid network.

Case 2 (JRADL $\neq$ 0)

DATA: A, B, C — 3F10.6

A, B, C — are coefficients in the equation, radius $R = A + Bs + Cs^2$, which specifies the duct wall shape. Here s is measured in inches along the duct centre line from the entrance of the injection slot. These coefficients allow the calculation of all radii (inches) and wall slopes (radians). For a duct of constant radius B = C = 0. For a tapered duct C = 0. See below.



format

2.2 Wall Bleed Velocity

DATA: JV — I2

JV — is a flag to assist in setting up the streamwise distribution of wall bleed velocity. JV = 0 implies Case 1. Otherwise, Case 2 is assumed.

Case 1 (JV = 0)

DATA: VWALL(1), ...VWALL(J), ...VWALL(M) — 8F10.6 per card

VWALL(J) — is the wall bleed velocity (fps) at streamwise station J in the grid network.

Case 2 (JV ≠ 0)

DATA: VWALL(1), DVDX — 2F10.6

VWALL(1) — is the wall bleed velocity (fps) at streamwise station 1 (the point of injection) in the grid network.

DVDX — *is the linear gradient of wall bleed velocity (fps/inch).*

2.3 Free-Stream Temperature

DATA: JT — I2

JT — is a flag to assist in setting up the streamwise distribution of free-stream temperature. JT = 0 implies Case 1. Otherwise, Case 2 is assumed.

Case 1 (JT = 0)

DATA: TINF(1), ...TINF(J), ...TINF(M) — 8F10.6 per card

TINF(J) — is the free-stream temperature (°R) at streamwise station J in the grid network.

Case 2 (JT ≠ 0)

DATA: TINF(1), DTDX — 2F11.6

format

TINF(1) is the free-stream temperature (°R) at streamwise station 1 (the point of injection) in the grid network.

DTDX is the linear gradient of free-stream temperature (°R/inch).

2.4 Free-Stream Velocity and Static Pressure

DATA: PSLOT, PMAIN 2F15.10

PSLOT is the static pressure (psia) in the slot one station upstream of the point of injection.

PMAIN is the static pressure (psia) in the main stream one station upstream of the point of injection.

DATA: JSEP I2

JSEP is a flag to assist in setting up the streamwise distributions of free-stream velocity and pressure. JSEP = 0 implies Case 1. Otherwise, Case 2 is assumed.

Case 1 (JSEP = 0)

DATA: UINF(1), ...UINF(J), ...UINF(M) 8F10.6 per card

UINF(J) is the streamwise component of free-stream velocity (fps) at streamwise station J in the grid network.

DATA: PRES(1), ...PRES(J), ...PRES(M) 8F10.6 per card

PRES(J) is the static pressure (psia) at streamwise station J in the grid network.

Case 2 (JSEP ≠ 0)

DATA: JPAR I2

JPAR is a flag to assist in setting up the streamwise distributions of free-stream velocity and pressure. JPAR = 0 implies Case 2-1. Otherwise, Case 2-2 is assumed.

format

Case 2-1 (JSEP ≠ 0, JPAR = 0)

DATA: UINF(1) — F10.6

UINF(1) is the streamwise component of free-stream velocity (fps) at streamwise station 1 (the point of injection) in the grid network.

DATA: JPRES — I2

JPRES is a flag to assist in setting up the streamwise distributions of free-stream velocity and pressure. JPRES = 0 implies Case 2-1-1. Otherwise, Case 2-1-2 is assumed.

Case 2-1-1 (JSEP ≠ 0, JPAR = 0, JPRES = 0)

DATA: PRES(1), ...PRES(J), ...PRES(M) — 8F10.6 per card

PRES(J) is the static pressure (psia) at streamwise station J in the grid network.

Case 2-1-2 (JSEP ≠ 0, JPAR = 0, JPRES ≠ 0)

DATA: PRES(1), DPDX — 2F15.10

PRES(1) is the static pressure (psia) at streamwise station 1 (the point of injection) in the grid network.

DPDX is the linear gradient of static pressure (psia/inch).

Case 2-2 (JSEP ≠ 0, JPAR ≠ 0)

DATA: PRES(1) — F10.6

PRES(1) is the static pressure (psia) at streamwise station 1 (the point of injection) in the grid network.

DATA: JU — I2

JU is a flag to assist in setting up the streamwise distributions of free-stream velocity and pressure. JU = 0 implies Case 2-2-1. Otherwise, Case 2-2-2 is assumed.

		format
	Case 2-2-1 (JSEP $\neq$ 0, JPAR $\neq$ 0, JU = 0)	
	DATA: UINF(1), ...UINF(J), ...UINF(M)	8F10.6 per card
UINF(J)	is the streamwise component of free-stream velocity (fps) at streamwise station J in the grid network.	
	Case 2-2-2 (JSEP $\neq$ 0, JPAR $\neq$ 0, JU $\neq$ 0)	
	DATA: UINF(1), DUEDX	2F10.6
UINF(1)	is the streamwise component of free-stream velocity (fps) at streamwise station 1 (the point of injection) in the grid network.	
DUEDX	is the linear gradient of free-stream velocity (fps/inch).	

3.0 Input of Data Pertaining to Inflow Boundary Conditions

3.1 Transverse Velocity at the Point of Injection

DATA: JVEL		I2
JVEL	is a flag, used in conjunction with JSTRT (specified previously), to assist in setting up the transverse distribution of transverse velocity. JVEL = 0 implies Case 1. Otherwise, Case 2 is assumed.	
	Case 1 (JVEL = 0)	
	JSTRT = 0 implies Case 1-1. Otherwise, Case 1-2 is assumed.	
	Case 1-1 (JVEL = 0, JSTRT = 0)	
	DATA: VM1(1), ...VM1(J), ...VM1(N)	8F10.5 per card
VM1(J)	is the transverse component of velocity (fps) at transverse station J of the grid network.	
	Case 1-2 (JVEL = 0, JSTRT $\neq$ 0)	
	DATA: VM1(1), ...VM1(J), ...VM1(N1)	8F10.5 per card

format

VM1(J) is as above. Values of VM1(J) for N1 < J ≤ N will be read from a disk file.

Case 2 (JVEL ≠ 0)

JSTRT = 0 implies Case 2-1. Otherwise, Case 2-2 is assumed.

Case 2-1 (JVEL ≠ 0, JSTRT = 0)

DATA: none

VM1(J) is set to zero for all 1 ≤ J ≤ N.

Case 2-2 (JVEL ≠ 0, JSTRT ≠ 0)

DATA: none

VM1(J) is set to zero for all 1 ≤ J ≤ N1. Values of VM1(J) for N1 < J ≤ N will be read from a disk file.

3.2 Transverse Velocity One Station Upstream of Injection

Repeat 3.1 but for array VM2.

3.3 Temperature at the Point of Injection

DATA: JT I2

JT is a flag, used in conjunction with JSTRT (specified previously), to assist in setting up the transverse distribution of temperature. JT = 0 implies Case 1. Otherwise, Case 2 is assumed.

Case 1 (JT = 0)

JSTRT = 0 implies Case 1-1. Otherwise, Case 1-2 is assumed.

format

Case 1-1 (JT = 0, JSTRT = 0)

DATA: TM1(1), ...TM1(J), ...TM1(N) — 8F10.5 per card

TM1(J) is the temperature (°R) at transverse station J of the grid network.

Case 1-2 (JT = 0, JSTRT ≠ 0)

DATA: TM1(1), ...TM1(J), ...TM1(N1) — 8F10.5 per card

TM1(J) is as above. Values of TM1(J) for $N1 < J \le N$ will be read from a disk file.

Case 2 (JT ≠ 0)

JSTRT = 0 implies Case 2-1. Otherwise, Case 2-2 is assumed.

Case 2-1 (JT ≠ 0, JSTRT = 0)

DATA: TINF2, TINF1 — 2F10.5

TINF2 is the uniform temperature (°R) of the fluid in the injection slot.

TINF1 is the uniform temperature (°R) of the main-stream fluid.

Case 2-2 (JT ≠ 0, JSTRT ≠ 0)

DATA: TINF2 — F10.5

TINF2 is as above. The temperature profile for the main stream will be read from a disk file.

3.4 Temperature One Station Upstream of Injection

Repeat 3.3 but for array TM2.

format

3.5 Streamwise Velocity at the Point of Injection

DATA: JVEL | I2

JVEL is a flag to assist in setting up the transverse distribution of streamwise velocity in the injection slot. JVEL = 0 implies Case 1. Otherwise, Case 2 is assumed.

Case 1 (JVEL = 0)

DATA: UM1(1), ...UM1(J), ...UM1(N1) | 8F10.5 per card

UM1(J) is the streamwise component of velocity (fps) at transverse station J of the grid network.

Case 2 (JVEL ≠ 0)

DATA: UDEL2, DELT2, PARM2 | 3F10.5

UDEL2 is the streamwise core velocity (fps) in the injection slot.

DELT2 is the thickness (inches) of both slot boundary layers. DELT2 must be less than half the slot width.

PARM2 is the law of the wake profile parameter for the slot boundary layers.

The above three parameters are used in conjunction with the law of the wall and the law of the wake to compute the streamwise velocity profile in the slot. The main-stream velocity profile is dealt with below. JSTRT = 0 implies Case 1. Otherwise, Case 2 is assumed.

Case 1 (JSTRT = 0)

DATA: JVEL | I2

JVEL is a flag, used in conjunction with JSTRT (specified previously), to assist in setting up the transverse distribution of streamwise velocity in the main stream. JVEL = 0 implies Case 1-1. Otherwise, Case 1-2 is assumed.

		format
	<u>Case 1-1 (JSTRT = 0, JVEL = 0)</u>	
	<u>DATA</u>: UM1(N2), ...UM1(J), ...UM1(N)	8F10.5 per card
UM1(J)	is as above.	
	<u>Case 1-2 (JSTRT = 0, JVEL ≠ 0)</u>	
	<u>DATA</u>: DELT1	F10.5
DELT1	is the main-stream boundary-layer thickness (inches).	
	<u>DATA</u>: JDAT	I2
JDAT	is a flag, used in conjunction with JSTRT and JVEL, to assist in setting up the transverse distribution of stream-wise velocity in the main stream. JDAT = 0 implies Case 1-2-1. Otherwise, Case 1-2-2 is assumed.	
	<u>Case 1-2-1 (JSTRT = 0, JVEL ≠ 0, JDAT = 0)</u>	
	DATA: UDEL1, CF	2F15.10
UDEL1	is the main-stream outer edge velocity (fps).	
CF	is the skin friction coefficient associated with the main stream.	
	<u>Case 1-2-2 (JSTRT = 0, JVEL ≠ 0, JDAT ≠ 0)</u>	
	<u>DATA</u>: UDEL1, PARM1	2F15.10
UDEL1	is as above.	
PARM1	is the law of the wake profile parameter for the main-stream boundary layer.	
	<u>Case 2 (JSTRT ≠ 0)</u>	
	<u>DATA</u>: none	
	The transverse distribution of streamwise velocity will be read from a disk file.	

format

3.6 Streamwise Velocity One Station Upstream of Injection

Repeat 3.5 but for array UM2.

Sample Data Deck and Results

Consider the following hypothetical case. Air at an ambient temperature of 530°R is drawn through an injection of 2-inch length and 0.75-inch width which completely surrounds the circumference of a duct of 28-inch outside diameter and 0.06-inch wall thickness. The slot boundary layers are 0.25 inches thick and have a profile parameter (after Coles) of 0.1411, corresponding to a core velocity of 48.5 fps. This entrained stream interacts with a main exhaust stream whose core temperature and velocity are 1048°R and 151.9 fps, respectively. The main-stream boundary layer is 2 inches thick and exhibits a profile parameter of 0.55. Both flows are parallel with no transverse components of velocity, pressure gradients or heat transfer upstream of their interaction with one another. The gases, which are assumed to behave like air, mix in a turbulent fashion in a cylindrical duct of 12-inch overall length and 0.06-inch wall thickness. The static pressure varies linearly along the duct from 13.384368 to 13.389323 psia.

A grid network of 5.25-inch height and 10-inch length (from x = 2 to x = 12 inches) will be used. The streamwise step size will be 1 inch and the finest transverse step size will be 0.00075 inches.

In addition to turbulent mixing other modes of heat transfer exist. The film-cooled duct of emissivity 0.95 receives radiative heat from an upstream source whose temperature and emissivity are 571.5°R and 1.0, respectively. As well, the duct radiates heat to a cool downstream source possessing a temperature of 530°R and emissivity of 1.0. The radiation shape factors for these energy exchanges are summarized in Table B-I below.

distance from slot exit (inches)	factor from hot upstream source to duct	factor from duct to downstream cold source
1	0.463	0.048
2	0.430	0.051
3	0.398	0.055
4	0.369	0.058
5	0.342	0.062
6	0.316	0.066
7	0.293	0.071
8	0.271	0.076
9	0.251	0.081
10	0.232	0.087

TABLE B-I: Radiation Shape Factors for Sample Problem

A final radiative heat-transfer process is one from the exhaust gas to the duct wall. For these purposes the gas is assumed to have an emissivity of 0.05 and the effective shape factor is considered to be unity. Radiation between neighbouring regions of the duct is ignored.

A sample data deck for this problem appears in Figure B-1. A portion of the output showing results of the iterative solution procedure appears in Figure B-2. These results are illustrated graphically in Figure 8. The example just presented is actually the first slot of the three-slot configuration shown in the figure.

```
//GO.SYSIN DD *

1 1 0 1 3 1
 0.75      2.00      1.00        .00075  12.00     5.25      .060      .060
  13.4      530.         53.35      572.
1
14.75      .0        .0
1
  .0       .0
1
1048.       .0
 13.384368     13.384368
1
0
151.9
1
 13.384368       .0004955555
1
1
1
530.     1048.
1
530.     1048.
1
 48.50      0.25      0.1411
1
  2.0
1
151.9           0.55
1
 48.50      0.25      0.1411
1
  2.0
1
151.9           0.55

/*
```

Figure B-1: A Sample Data Deck for Program Film.

FILM COOLING INITIALIZATION SUMMARY

1) GENERAL INFORMATION

-CONFIGURATION: SLOT NUMBER 1 OF A 3 SLOT FACILITY

-COORDINATE SYSTEM: AXISYMMETRIC

2) GRID GEOMETRY INFORMATION

-SLOT HEIGHT: 0.75 INCHES

-SLOT ENTRY LENGTH: 2.00 INCHES

-LONGITUDINAL CALCULATION INTERVAL: FROM X = 2.00 INCHES TO X = 12.00 INCHES

-TRANSVERSE CALCULATION INTERVAL: FROM Y = 0.00 INCHES TO Y = 5.25 INCHES

-LONGITUDINAL STEP SIZE: 1.00000 INCHES

-FINEST RADIAL STEP SIZE: 0.000750 INCHES

-INNER WALL THICKNESS: 0.0600 INCHES

-OUTER WALL THICKNESS: 0.0600 INCHES

3) ATMOSPHERIC INFORMATION

-AMBIENT PRESSURE: 13.4000 PSIA

-AMBIENT TEMPERATURE: 530.000 °R

4) FLUID DYNAMIC INFORMATION

-VON KARMAN'S LAW OF THE WALL CONSTANT: 0.4350

-ADDITIVE CONSTANT IN LAW OF THE WALL: 5.240

-VAN DRIEST'S DAMPING PARAMETER: 26.00

-FLUID GAS CONSTANT: 53.350 FT-LBF/LBM-R

5) STREAMWISE BOUNDARY CONDITIONS

-STREAMWISE DISTRIBUTION OF FREE-STREAM VELOCITY:

X (INCHES)		VELOCITY U (FPS)					
2.000	*	0.1519000D+03	0.1514577D+03	0.1510142D+03	0.1505694D+03	0.1501233D+03	0.1496760D+03
8.000	*	0.1492273D+03	0.1487773D+03	0.1483259D+03	0.1478732D+03	0.1474192D+03	

-STREAMWISE DISTRIBUTION OF STATIC PRESSURE:

X (INCHES)		STATIC PRESSURE P (PSIA)					
2.000	*	0.1338437D+02	0.1338486D+02	0.1338536D+02	0.1338585D+02	0.1338635D+02	0.1338685D+02
8.000	*	0.1338734D+02	0.1338784D+02	0.1338833D+02	0.1338883D+02	0.1338932D+02	

-STREAMWISE DISTRIBUTION OF FREE-STREAM TEMPERATURE:

X (INCHES)		TEMPERATURE T (°R)					
2.000	*	0.1048000D+04	0.1048000D+04	0.1048000D+04	0.1048000D+04	0.1048000D+04	0.1048000D+04
8.000	*	0.1048000D+04	0.1048000D+04	0.1048000D+04	0.1048000D+04	0.1048000D+04	

-STREAMWISE DISTRIBUTION OF BLEED VELOCITY AT THE WALL:

X (INCHES)		VELOCITY V (FPS)					
2.000	*	0.0	0.0	0.0	0.0	0.0	0.0
8.000	*	0.0	0.0	0.0	0.0	0.0	

-STREAMWISE DISTRIBUTION OF CHANNEL RADIUS:

X (INCHES)		CHANNEL RADIUS R (INCHES)					
2.000	*	0.1475000D+02	0.1475000D+02	0.1475000D+02	0.1475000D+02	0.1475000D+02	0.1475000D+02
8.000	*	0.1475000D+02	0.1475000D+02	0.1475000D+02	0.1475000D+02	0.1475000D+02	

-STREAMWISE DISTRIBUTION OF WALL SLOPE:

X (INCHES)		WALL SLOPE M (DEGREES)					
2.000	*	0.0	0.0	0.0	0.0	0.0	0.0
8.000	*	0.0	0.0	0.0	0.0	0.0	

Figure B-2: A Sample Printout for Program Film (Page 1).

B) INFLOW BOUNDARY CONDITIONS

A) AT THE POINT OF INJECTION

-TRANSVERSE DISTRIBUTION OF STREAMWISE VELOCITY:

Y (INCHES)		VELOCITY U (FPS)									
0.0	*	0.0	0.22410D+01	0.44803D+01	0.67079D+01	0.89002D+01	0.11021D+02	0.13028D+02	0.14890D+02	0.16588D+02	0.18123D+02
0.0075	*	0.19502D+02	0.20740D+02	0.21852D+02	0.22854D+02	0.23760D+02	0.24583D+02	0.25332D+02	0.26019D+02	0.26650D+02	0.27232D+02
0.0150	*	0.27770D+02	0.28271D+02	0.28738D+02	0.29174D+02	0.29583D+02	0.29968D+02	0.30331D+02	0.30674D+02	0.30998D+02	0.31307D+02
0.0225	*	0.31600D+02	0.31879D+02	0.32145D+02	0.32400D+02	0.32644D+02	0.32878D+02	0.33103D+02	0.33319D+02	0.33527D+02	0.33728D+02
0.0300	*	0.33922D+02	0.34109D+02	0.34290D+02	0.34465D+02	0.34635D+02	0.34800D+02	0.34960D+02	0.35116D+02	0.35267D+02	0.35415D+02
0.0375	*	0.35558D+02	0.35698D+02	0.35834D+02	0.35967D+02	0.36097D+02	0.36224D+02	0.36349D+02	0.36470D+02	0.36589D+02	0.36706D+02
0.0450	*	0.36820D+02	0.36932D+02	0.37041D+02	0.37149D+02	0.37255D+02	0.37359D+02	0.37461D+02	0.37561D+02	0.37659D+02	0.37756D+02
0.0525	*	0.37852D+02	0.37946D+02	0.38038D+02	0.38129D+02	0.38219D+02	0.38307D+02	0.38394D+02	0.38480D+02	0.38565D+02	0.38648D+02
0.0600	*	0.38731D+02	0.38812D+02	0.38893D+02	0.38972D+02	0.39050D+02	0.39128D+02	0.39204D+02	0.39280D+02	0.39355D+02	0.39429D+02
0.0675	*	0.39502D+02	0.39574D+02	0.39646D+02	0.39716D+02	0.39786D+02	0.39856D+02	0.39924D+02	0.39992D+02	0.40060D+02	0.40126D+02
0.0750	*	0.40192D+02	0.40258D+02	0.40323D+02	0.40387D+02	0.40451D+02	0.40514D+02	0.40576D+02	0.40638D+02	0.40700D+02	0.40761D+02
0.0825	*	0.40822D+02	0.40882D+02	0.40941D+02	0.41000D+02	0.41059D+02	0.41117D+02	0.41175D+02	0.41232D+02	0.41289D+02	0.41345D+02
0.0900	*	0.41401D+02	0.41457D+02	0.41512D+02	0.41567D+02	0.41622D+02	0.41676D+02	0.41730D+02	0.41783D+02	0.41836D+02	0.41889D+02
0.0975	*	0.41941D+02	0.41993D+02	0.42045D+02	0.42096D+02	0.42147D+02	0.42198D+02	0.42249D+02	0.42299D+02	0.42348D+02	0.42398D+02
0.1050	*	0.42447D+02	0.42496D+02	0.42545D+02	0.42593D+02	0.42641D+02	0.42689D+02	0.42737D+02	0.42784D+02	0.42831D+02	0.42878D+02
0.1125	*	0.42924D+02	0.42971D+02	0.43017D+02	0.43062D+02	0.43108D+02	0.43153D+02	0.43198D+02	0.43243D+02	0.43288D+02	0.43332D+02
0.1200	*	0.43376D+02	0.43420D+02	0.43464D+02	0.43507D+02	0.43550D+02	0.43593D+02	0.43636D+02	0.43679D+02	0.43721D+02	0.43763D+02
0.1275	*	0.43805D+02	0.43847D+02	0.43889D+02	0.43930D+02	0.43971D+02	0.44012D+02	0.44053D+02	0.44093D+02	0.44134D+02	0.44174D+02
0.1350	*	0.44214D+02	0.44254D+02	0.44293D+02	0.44333D+02	0.44372D+02	0.44411D+02	0.44450D+02	0.44489D+02	0.44527D+02	0.44566D+02
0.1425	*	0.44604D+02	0.44642D+02	0.44679D+02	0.44717D+02	0.44755D+02	0.44792D+02	0.44829D+02	0.44866D+02	0.44903D+02	0.44939D+02
0.1500	*	0.44976D+02	0.45012D+02	0.45048D+02	0.45084D+02	0.45120D+02	0.45155D+02	0.45191D+02	0.45226D+02	0.45261D+02	0.45296D+02
0.1575	*	0.45331D+02	0.45365D+02	0.45400D+02	0.45434D+02	0.45468D+02	0.45502D+02	0.45536D+02	0.45570D+02	0.45603D+02	0.45637D+02
0.1650	*	0.45670D+02	0.45703D+02	0.45736D+02	0.45769D+02	0.45801D+02	0.45834D+02	0.45866D+02	0.45898D+02	0.45930D+02	0.45962D+02
0.1725	*	0.45994D+02	0.46025D+02	0.46057D+02	0.46088D+02	0.46119D+02	0.46150D+02	0.46181D+02	0.46211D+02	0.46242D+02	0.46272D+02
0.1800	*	0.46302D+02	0.46332D+02	0.46362D+02	0.46392D+02	0.46422D+02	0.46451D+02	0.46480D+02	0.46510D+02	0.46539D+02	0.46568D+02
0.1875	*	0.46596D+02	0.46625D+02	0.46653D+02	0.46682D+02	0.46710D+02	0.46738D+02	0.46766D+02	0.46793D+02	0.46821D+02	0.46848D+02
0.1950		0.46876D+02	0.46903D+02	0.46930D+02	0.46957D+02	0.46984D+02	0.47010D+02	0.47037D+02	0.47063D+02	0.47089D+02	0.47115D+02
0.2025	*	0.47141D+02	0.47167D+02	0.47193D+02	0.47218D+02	0.47243D+02	0.47269D+02	0.47294D+02	0.47319D+02	0.47343D+02	0.47368D+02
0.2100	*	0.47393D+02	0.47417D+02	0.47441D+02	0.47465D+02	0.47489D+02	0.47513D+02	0.47537D+02	0.47560D+02	0.47584D+02	0.47607D+02
0.2175	*	0.47630D+02	0.47653D+02	0.47676D+02	0.47699D+02	0.47721D+02	0.47744D+02	0.47766D+02	0.47788D+02	0.47810D+02	0.47832D+02
0.2250	*	0.47854D+02	0.47876D+02	0.47897D+02	0.47919D+02	0.47940D+02	0.47961D+02	0.47982D+02	0.48003D+02	0.48024D+02	0.48044D+02
0.2325	*	0.48065D+02	0.48085D+02	0.48105D+02	0.48126D+02	0.48145D+02	0.48165D+02	0.48185D+02	0.48205D+02	0.48224D+02	0.48243D+02
0.2400	*	0.48262D+02	0.48281D+02	0.48300D+02	0.48319D+02	0.48338D+02	0.48356D+02	0.48375D+02	0.48393D+02	0.48411D+02	0.48429D+02
0.2475	*	0.48447D+02	0.48465D+02	0.48482D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02
0.2550	*	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02
0.2625	*	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02
0.2700	*	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02
0.2775	*	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02
0.2850	*	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02
0.2925	*	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02
0.3000	*	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02
0.3075	*	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02
0.3150	*	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02
0.3225	*	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02
0.3300	*	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02
0.3375	*	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02
0.3450	*	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02
0.3525	*	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02
0.3600	*	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02
0.3675	*	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02
0.3750	*	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02
0.4500	*	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48440D+02	0.48253D+02	0.48053D+02
0.5250	*	0.47840D+02	0.47613D+02	0.47372D+02	0.47117D+02	0.46849D+02	0.46565D+02	0.46267D+02	0.45955D+02	0.45627D+02	0.45283D+02
0.6000	*	0.44923D+02	0.44546D+02	0.44151D+02	0.43737D+02	0.43302D+02	0.42845D+02	0.42363D+02	0.41852D+02	0.41309D+02	0.40728D+02
0.6750	*	0.40103D+02	0.39422D+02	0.38673D+02	0.37837D+02	0.36886D+02	0.35775D+02	0.34431D+02	0.32714D+02	0.30311D+02	0.26224D+02
0.7500	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.58321D+02
0.8250	*	0.68024D+02	0.73702D+02	0.77732D+02	0.80860D+02	0.83418D+02	0.85582D+02	0.87459D+02	0.89117D+02	0.90601D+02	0.91947D+02
0.9000	*	0.93177D+02	0.94310D+02	0.95362D+02	0.96343D+02	0.97263D+02	0.98129D+02	0.98947D+02	0.99724D+02	0.10046D+03	0.10117D+03
0.9750	*	0.10184D+03	0.10249D+03	0.10311D+03	0.10370D+03	0.10428D+03	0.10484D+03	0.10537D+03	0.10590D+03	0.10640D+03	0.10689D+03
1.0500	*	0.10737D+03	0.10783D+03	0.10829D+03	0.10873D+03	0.10916D+03	0.10958D+03	0.10999D+03	0.11040D+03	0.11079D+03	0.11118D+03
1.1250	*	0.11156D+03	0.11193D+03	0.11230D+03	0.11266D+03	0.11301D+03	0.11336D+03	0.11370D+03	0.11404D+03	0.11437D+03	0.11470D+03
1.2000	*	0.11502D+03	0.11534D+03	0.11566D+03	0.11597D+03	0.11628D+03	0.11658D+03	0.11688D+03	0.11718D+03	0.11747D+03	0.11776D+03
1.2750	*	0.11805D+03	0.11833D+03	0.11862D+03	0.11890D+03	0.11917D+03	0.11945D+03	0.11972D+03	0.11999D+03	0.12026D+03	0.12052D+03
1.3500	*	0.12079D+03	0.12105D+03	0.12131D+03	0.12156D+03	0.12182D+03	0.12207D+03	0.12233D+03	0.12258D+03	0.12283D+03	0.12307D+03
1.4250	*	0.12332D+03	0.12356D+03	0.12381D+03	0.12405D+03	0.12429D+03	0.12453D+03	0.12477D+03	0.12500D+03	0.12524D+03	0.12547D+03
1.5000	*	0.12570D+03	0.12797D+03	0.13015D+03	0.13223D+03	0.13424D+03	0.13617D+03	0.13801D+03	0.13978D+03	0.14145D+03	0.14303D+03
2.2500	*	0.14451D+03	0.14588D+03	0.14715D+03	0.14829D+03	0.14932D+03	0.15022D+03	0.15099D+03	0.15164D+03	0.15190D+03	0.15190D+03
3.0000	*	0.15190D+03	0.15190D+03	0.15190D+03	0.15190D+03	0.15190D+03	0.15190D+03	0.15190D+03	0.15190D+03	0.15190D+03	0.15190D+03
3.7500	*	0.15190D+03	0.15190D+03	0.15190D+03	0.15190D+03	0.15190D+03	0.15190D+03	0.15190D+03	0.15190D+03	0.15190D+03	0.15190D+03
4.5000	*	0.15190D+03	0.15190D+03	0.15190D+03	0.15190D+03	0.15190D+03	0.15190D+03	0.15190D+03	0.15190D+03	0.15190D+03	0.15190D+03
5.2500	*	0.15190D+03									

BOUNDARY LAYER AND RELATED PARAMETERS

PARAMETER	SECONDARY STREAM	PRIMARY STREAM
BOUNDARY LAYER THICKNESS (INCHES)	0.25000000D+00	0.20000000D+01
DISPLACEMENT THICKNESS (INCHES)	0.36906664D-01	0.27785890D+00
MOMENTUM DEFICIT THICKNESS (INCHES)	0.24863680D-01	0.20618490D+00
VELOCITY PROFILE SHAPE FACTOR	0.14843600D+01	0.13476200D+01
FRICTION VELOCITY (FPS)	0.25580000D+01	0.60884190D+01

THE MASS ISSUING FROM THE SLOT IS 0.18181340D+00 LBM/SEC/FT.

Figure B-2: A Sample Printout for Program Film (Page 2).

*TRANSVERSE DISTRIBUTION OF TRANSVERSE VELOCITY:

Y (INCHES)		VELOCITY V (FPS)									
0.0	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0075	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0150	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0225	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0300	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0375	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0450	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0525	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0600	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0675	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0750	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0825	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0900	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0975	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.1050	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.1125	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.1200	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.1275	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.1350	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.1425	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.1500	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.1575	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.1650	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.1725	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.1800	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.1875	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.1950	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.2025	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.2100	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.2175	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.2250	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.2325	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.2400	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.2475	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.2550	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.2625	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.2700	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.2775	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.2850	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.2925	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.3000	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.3075	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.3150	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.3225	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.3300	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.3375	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.3450	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.3525	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.3600	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.3675	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.3750	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.4500	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.5250	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.6000	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.6750	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.7500	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.8250	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.9000	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.9750	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.0500	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.1250	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.2000	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.2750	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.3500	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.4250	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.5000	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2.2500	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3.0000	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3.7500	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4.5000	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5.2500	*	0.0									

*TRANSVERSE DISTRIBUTION OF TEMPERATURE:

Y (INCHES)		TEMPERATURE T (°R)									
0.0	*	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03
0.0075	*	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03
0.0150	*	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03
0.0225	*	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03
0.0300	*	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03
0.0375	*	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03
0.0450	*	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03
0.0525	*	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03
0.0600	*	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03
0.0675	*	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03
0.0750	*	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03
0.0825	*	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03
0.0900	*	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03
0.0975	*	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03
0.1050	*	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03
0.1125	*	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03
0.1200	*	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03
0.1275	*	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03
0.1350	*	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03

Figure B-2: A Sample Printout for Program Film (Page 3).

0.1425	*	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03
0.1500	*	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03
0.1575	*	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03
0.1650	*	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03
0.1725	*	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03
0.1800	*	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03
0.1875	*	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03
0.1950	*	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03
0.2025	*	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03
0.2100	*	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03
0.2175	*	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03
0.2250	*	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03
0.2325	*	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03
0.2400	*	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03
0.2475	*	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03
0.2550	*	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03
0.2625	*	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03
0.2700	*	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03
0.2775	*	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03
0.2850	*	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03
0.2925	*	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03
0.3000	*	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03
0.3075	*	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03
0.3150	*	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03
0.3225	*	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03
0.3300	*	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03
0.3375	*	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03
0.3450	*	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03
0.3525	*	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03
0.3600	*	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03
0.3675	*	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03
0.3750	*	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03
0.4500	*	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03
0.5250	*	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03
0.6000	*	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03
0.6750	*	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03
0.7500	*	0.53000D+03	0.59475D+03	0.65950D+03	0.72425D+03	0.78900D+03	0.85375D+03	0.91850D+03	0.98325D+03	0.10480D+04	0.10480D+04
0.8250	*	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04
0.[illegible]	*	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04
0.[illegible]	*	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04
1.[illegible]00	*	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04
1.12[illegible]0	*	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04
1.2[illegible]0	*	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04
1.27[illegible]	*	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04
1.3[illegible]	*	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04
1.4250	*	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04
1.5[illegible]0	*	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04
2.2[illegible]0	*	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04
3.[illegible]00	*	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04
3.7500	*	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04
4.5000	*	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04
5.2500	*	0.10480D+04									

B) ONE STATION UPSTREAM OF THE POINT OF INJECTION

*TRANSVERSE DISTRIBUTION OF STREAMWISE VELOCITY:

Y (INCHES) VELOCITY U (FPS)

0.0	*	0.0	0.22410D+01	0.44803D+01	0.67079D+01	0.89002D+01	0.11021D+02	0.13028D+02	0.14890D+02	0.16588D+02	0.18123D+02
0.0075	*	0.19502D+02	0.20740D+02	0.21852D+02	0.22854D+02	0.23760D+02	0.24583D+02	0.25332D+02	0.26019D+02	0.26650D+02	0.27232D+02
0.0150	*	0.27770D+02	0.28271D+02	0.28738D+02	0.29174D+02	0.29583D+02	0.29968D+02	0.30331D+02	0.30674D+02	0.30998D+02	0.31307D+02
0.0225	*	0.31600D+02	0.31879D+02	0.32145D+02	0.32400D+02	0.32644D+02	0.32878D+02	0.33103D+02	0.33319D+02	0.33527D+02	0.33728D+02
0.0300	*	0.33922D+02	0.34109D+02	0.34290D+02	0.34465D+02	0.34635D+02	0.34800D+02	0.34960D+02	0.35116D+02	0.35267D+02	0.35415D+02
0.0375	*	0.35558D+02	0.35698D+02	0.35834D+02	0.35967D+02	0.36097D+02	0.36224D+02	0.36349D+02	0.36470D+02	0.36589D+02	0.36706D+02
0.0450	*	0.36820D+02	0.36932D+02	0.37041D+02	0.37149D+02	0.37255D+02	0.37359D+02	0.37461D+02	0.37561D+02	0.37659D+02	0.37756D+02
0.0525	*	0.37852D+02	0.37946D+02	0.38038D+02	0.38129D+02	0.38219D+02	0.38307D+02	0.38394D+02	0.38480D+02	0.38565D+02	0.38648D+02
0.0600	*	0.38731D+02	0.38812D+02	0.38893D+02	0.38972D+02	0.39050D+02	0.39128D+02	0.39204D+02	0.39280D+02	0.39355D+02	0.39429D+02
0.0675	*	0.39502D+02	0.39574D+02	0.39646D+02	0.39716D+02	0.39786D+02	0.39856D+02	0.39924D+02	0.39992D+02	0.40060D+02	0.40126D+02
0.0750	*	0.40192D+02	0.40258D+02	0.40323D+02	0.40387D+02	0.40451D+02	0.40514D+02	0.40576D+02	0.40638D+02	0.40700D+02	0.40761D+02
0.0825	*	0.40822D+02	0.40882D+02	0.40941D+02	0.41000D+02	0.41059D+02	0.41117D+02	0.41175D+02	0.41232D+02	0.41289D+02	0.41345D+02
0.0900	*	0.41401D+02	0.41457D+02	0.41512D+02	0.41567D+02	0.41622D+02	0.41676D+02	0.41730D+02	0.41783D+02	0.41836D+02	0.41889D+02
0.0975	*	0.41941D+02	0.41993D+02	0.42045D+02	0.42096D+02	0.42147D+02	0.42198D+02	0.42249D+02	0.42299D+02	0.42348D+02	0.42398D+02
0.1050	*	0.42447D+02	0.42496D+02	0.42545D+02	0.42593D+02	0.42641D+02	0.42689D+02	0.42737D+02	0.42784D+02	0.42831D+02	0.42878D+02
0.1125	*	0.42924D+02	0.42971D+02	0.43017D+02	0.43062D+02	0.43108D+02	0.43153D+02	0.43198D+02	0.43243D+02	0.43288D+02	0.43332D+02
0.1200	*	0.43376D+02	0.43420D+02	0.43464D+02	0.43507D+02	0.43550D+02	0.43593D+02	0.43636D+02	0.43679D+02	0.43721D+02	0.43763D+02
0.1275	*	0.43805D+02	0.43847D+02	0.43889D+02	0.43930D+02	0.43971D+02	0.44012D+02	0.44053D+02	0.44093D+02	0.44134D+02	0.44174D+02
0.1350	*	0.44214D+02	0.44254D+02	0.44293D+02	0.44333D+02	0.44372D+02	0.44411D+02	0.44450D+02	0.44489D+02	0.44527D+02	0.44566D+02
0.1425	*	0.44604D+02	0.44642D+02	0.44679D+02	0.44717D+02	0.44755D+02	0.44792D+02	0.44829D+02	0.44866D+02	0.44903D+02	0.44939D+02
0.1500	*	0.44976D+02	0.45012D+02	0.45048D+02	0.45084D+02	0.45120D+02	0.45155D+02	0.45191D+02	0.45226D+02	0.45261D+02	0.45296D+02
0.1575	*	0.45331D+02	0.45365D+02	0.45400D+02	0.45434D+02	0.45468D+02	0.45502D+02	0.45536D+02	0.45570D+02	0.45603D+02	0.45637D+02
0.1650	*	0.45670D+02	0.45703D+02	0.45736D+02	0.45769D+02	0.45801D+02	0.45834D+02	0.45866D+02	0.45898D+02	0.45930D+02	0.45962D+02
0.1725	*	0.45994D+02	0.46025D+02	0.46057D+02	0.46088D+02	0.46119D+02	0.46150D+02	0.46181D+02	0.46211D+02	0.46242D+02	0.46272D+02
0.1800	*	0.46302D+02	0.46332D+02	0.46362D+02	0.46392D+02	0.46422D+02	0.46451D+02	0.46480D+02	0.46510D+02	0.46539D+02	0.46568D+02
0.1875	*	0.46596D+02	0.46625D+02	0.46653D+02	0.46682D+02	0.46710D+02	0.46738D+02	0.46766D+02	0.46793D+02	0.46821D+02	0.46848D+02
0.1950	*	0.46876D+02	0.46903D+02	0.46930D+02	0.46957D+02	0.46984D+02	0.47010D+02	0.47037D+02	0.47063D+02	0.47089D+02	0.47115D+02
0.2025	*	0.47141D+02	0.47167D+02	0.47193D+02	0.47218D+02	0.47243D+02	0.47269D+02	0.47294D+02	0.47319D+02	0.47343D+02	0.47368D+02
0.2100	*	0.47393D+02	0.47417D+02	0.47441D+02	0.47465D+02	0.47489D+02	0.47513D+02	0.47537D+02	0.47560D+02	0.47584D+02	0.47607D+02
0.2175	*	0.47630D+02	0.47653D+02	0.47676D+02	0.47699D+02	0.47721D+02	0.47744D+02	0.47766D+02	0.47788D+02	0.47810D+02	0.47832D+02
0.2250	*	0.47854D+02	0.47876D+02	0.47897D+02	0.47919D+02	0.47940D+02	0.47961D+02	0.47982D+02	0.48003D+02	0.48024D+02	0.48044D+02
0.2325	*	0.48065D+02	0.48085D+02	0.48105D+02	0.48126D+02	0.48145D+02	0.48165D+02	0.48185D+02	0.48205D+02	0.48224D+02	0.48243D+02
0.2400	*	0.48262D+02	0.48281D+02	0.48300D+02	0.48319D+02	0.48338D+02	0.48356D+02	0.48375D+02	0.48393D+02	0.48411D+02	0.48429D+02
0.2475	*	0.48447D+02	0.48465D+02	0.48482D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02
0.2550	*	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02
0.2625	*	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02
0.2700	*	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02
0.2775	*	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02
0.2850	*	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02
0.2925	*	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02
0.3000	*	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02
0.3075	*	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02

Figure B-2: A Sample Printout for Program Film (Page 4).

0.3150	*	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02
0.3225	*	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02
0.3300	*	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02
0.3375	*	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02
0.3450	*	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02
0.3525	*	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02
0.3600	*	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02
0.3675	*	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02
0.3750	*	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02
0.4500	*	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48500D+02	0.48440D+02	0.48253D+02	0.48053D+02
0.5250	*	0.47840D+02	0.47613D+02	0.47372D+02	0.47117D+02	0.46849D+02	0.46565D+02	0.46267D+02	0.45955D+02	0.45627D+02	0.45283D+02
0.6000	*	0.44923D+02	0.44546D+02	0.44151D+02	0.43737D+02	0.43302D+02	0.42845D+02	0.42363D+02	0.41852D+02	0.41309D+02	0.40728D+02
0.6750	*	0.40103D+02	0.39422D+02	0.38673D+02	0.37837D+02	0.36886D+02	0.35775D+02	0.34431D+02	0.32714D+02	0.30311D+02	0.26224D+02
0.7500	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.58321D+02
0.8250	*	0.68024D+02	0.73702D+02	0.77732D+02	0.80860D+02	0.83418D+02	0.85582D+02	0.87459D+02	0.89117D+02	0.90601D+02	0.91947D+02
0.9000	*	0.93177D+02	0.94310D+02	0.95362D+02	0.96343D+02	0.97263D+02	0.98129D+02	0.98947D+02	0.99724D+02	0.10046D+03	0.10117D+03
0.9750	*	0.10184D+03	0.10249D+03	0.10311D+03	0.10370D+03	0.10428D+03	0.10484D+03	0.10537D+03	0.10590D+03	0.10640D+03	0.10689D+03
1.0500	*	0.10737D+03	0.10783D+03	0.10829D+03	0.10873D+03	0.10916D+03	0.10958D+03	0.10999D+03	0.11040D+03	0.11079D+03	0.11118D+03
1.1250	*	0.11156D+03	0.11193D+03	0.11230D+03	0.11266D+03	0.11301D+03	0.11336D+03	0.11370D+03	0.11404D+03	0.11437D+03	0.11470D+03
1.2000	*	0.11502D+03	0.11534D+03	0.11566D+03	0.11597D+03	0.11628D+03	0.11658D+03	0.11688D+03	0.11718D+03	0.11747D+03	0.11776D+03
1.2750	*	0.11805D+03	0.11833D+03	0.11862D+03	0.11890D+03	0.11917D+03	0.11945D+03	0.11972D+03	0.11999D+03	0.12026D+03	0.12052D+03
1.3500	*	0.12079D+03	0.12105D+03	0.12131D+03	0.12156D+03	0.12182D+03	0.12207D+03	0.12233D+03	0.12258D+03	0.12283D+03	0.12307D+03
1.4250	*	0.12332D+03	0.12356D+03	0.12381D+03	0.12405D+03	0.12429D+03	0.12453D+03	0.12477D+03	0.12500D+03	0.12524D+03	0.12547D+03
1.5000	*	0.12570D+03	0.12797D+03	0.13015D+03	0.13223D+03	0.13424D+03	0.13617D+03	0.13801D+03	0.13978D+03	0.14145D+03	0.14303D+03
2.2500	*	0.14451D+03	0.14588D+03	0.14715D+03	0.14829D+03	0.14932D+03	0.15022D+03	0.15099D+03	0.15164D+03	0.15190D+03	0.15190D+03
3.0000	*	0.15190D+03	0.15190D+03	0.15190D+03	0.15190D+03	0.15190D+03	0.15190D+03	0.15190D+03	0.15190D+03	0.15190D+03	0.15190D+03
3.7500	*	0.15190D+03	0.15190D+03	0.15190D+03	0.15190D+03	0.15190D+03	0.15190D+03	0.15190D+03	0.15190D+03	0.15190D+03	0.15190D+03
4.5000	*	0.15190D+03	0.15190D+03	0.15190D+03	0.15190D+03	0.15190D+03	0.15190D+03	0.15190D+03	0.15190D+03	0.15190D+03	0.15190D+03
5.2500	*	0.15190D+03									

BOUNDARY LAYER AND RELATED PARAMETERS

PARAMETER	SECONDARY STREAM	PRIMARY STREAM
BOUNDARY LAYER THICKNESS (INCHES)	0.2500000D+00	0.2000000D+01
DISPLACEMENT THICKNESS (INCHES)	0.3690664D-01	0.2778589D+00
MOMENTUM DEFICIT THICKNESS (INCHES)	0.2486368D-01	0.2061849D+00
VELOCITY PROFILE SHAPE FACTOR	0.1484360D+01	0.1347620D+01
FRICTION VELOCITY (FPS)	0.2558000D+01	0.6088419D+01

*TRANSVERSE DISTRIBUTION OF TRANSVERSE VELOCITY:

Y (INCHES)		VELOCITY V (FPS)									
0.0	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0075	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0150	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0225	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0300	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0375	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0450	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0525	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0600	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0675	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0750	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0825	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0900	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0975	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.1050	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.1125	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.1200	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.1275	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.1350	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.1425	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.1500	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.1575	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.1650	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.1725	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.1800	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.1875	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.1950	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.2025	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.2100	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.2175	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.2250	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.2325	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.2400	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.2475	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.2550	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.2625	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.2700	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.2775	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.2850	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.2925	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.3000	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.3075	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.3150	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.3225	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.3300	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.3375	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.3450	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.3525	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.3600	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.3675	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
[illegible]	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
[illegible]	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
[illegible]	*	[illegible]	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
[illegible]	*	[illegible]	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Figure B-2: A Sample Printout for Program Film (Page 5).

0.7500	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.8250	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.9000	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.9750	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.0500	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.1250	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.2000	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.2750	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.3500	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.4250	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.5000	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2.2500	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3.0000	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3.7500	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4.5000	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5.2500	*	0.0									

-TRANSVERSE DISTRIBUTION OF TEMPERATURE:

Y (INCHES)		TEMPERATURE T (°R)									
0.0	*	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03
0.0075	*	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03
0.0150	*	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03
0.0225	*	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03
0.0300	*	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03
0.0375	*	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03
0.0450	*	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03
0.0525	*	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03
0.0600	*	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03
0.0675	*	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03
0.0750	*	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03
0.0825	*	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03
0.0900	*	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03
0.0975	*	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03
0.1050	*	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03
0.1125	*	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03
0.1200	*	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03
0.1275	*	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03
0.1350	*	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03
0.1425	*	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03
0.1500	*	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03
0.1575	*	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03
0.1650	*	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03
0.1725	*	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03
0.1800	*	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03
0.1875	*	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03
0.1950	*	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03
0.2025	*	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03
0.2100	*	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03
0.2175	*	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03
0.2250	*	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03
0.2325	*	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03
0.2400	*	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03
0.2475	*	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03
0.2550	*	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03
0.2625	*	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03
0.2700	*	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03
0.2775	*	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03
0.2850	*	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03
0.2925	*	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03
0.3000	*	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03
0.3075	*	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03
0.3150	*	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03
0.3225	*	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03
0.3300	*	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03
0.3375	*	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03
0.3450	*	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03
0.3525	*	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03
0.3600	*	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03
0.3675	*	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03
0.3750	*	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03
0.4500	*	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03
0.5250	*	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03
0.6000	*	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03
0.6750	*	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03	0.53000D+03
0.7500	*	0.53000D+03	0.59475D+03	0.65950D+03	0.72425D+03	0.78900D+03	0.85375D+03	0.91850D+03	0.98325D+03	0.10480D+04	0.10480D+04
0.8250	*	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04
0.9000	*	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04
0.9750	*	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04
1.0500	*	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04
1.1250	*	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04
1.2000	*	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04
1.2750	*	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04
1.3500	*	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04
1.4250	*	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04
1.5000	*	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04
2.2500	*	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04
3.0000	*	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04
3.7500	*	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04
4.5000	*	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04	0.10480D+04
5.2500	*	0.10480D+04									

Figure B-2: A Sample Printout for Program Film (Page 6).

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*** STATION NUMBER   7     X =  0.6667 FEET

 TEMPERATURE ITERATION NUMBER  1

     VELOCITY ITERATION NUMBER  1

          DELT1        UDEL1        UTAU         VTMM         YOUT
       0.220993D+00 0.147735D+03 0.246899D+01 0.198565D+00 0.457226D-01

     VELOCITY FRACTIONAL DISPLACEMENT NORM = 0.339545D-01

     VELOCITY ITERATION NUMBER  2

          DELT1        UDEL1        UTAU         VTMM         YOUT
       0.226828D+00 0.147735D+03 0.253176D+01 0.194756D+00 0.469299D-01

     VELOCITY FRACTIONAL DISPLACEMENT NORM = 0.397969D-02

     VELOCITY ITERATION NUMBER  3

          DELT1        UDEL1        UTAU         VTMM         YOUT
       0.226382D+00 0.147735D+03 0.256700D+01 0.191993D+00 0.468376D-01

     VELOCITY FRACTIONAL DISPLACEMENT NORM = 0.182117D-02

     VELOCITY ITERATION NUMBER  4

          DELT1        UDEL1        UTAU         VTMM         YOUT
       0.225553D+00 0.147735D+03 0.257508D+01 0.196303D+00 0.466662D-01

     VELOCITY FRACTIONAL DISPLACEMENT NORM = 0.387390D-03

     VELOCITY ITERATION NUMBER  5

          DELT1        UDEL1        UTAU         VTMM         YOUT
       0.225092D+00 0.147735D+03 0.257753D+01 0.192190D+00 0.465707D-01

     VELOCITY FRACTIONAL DISPLACEMENT NORM = 0.195595D-03

     VELOCITY ITERATION NUMBER  6

          DELT1        UDEL1        UTAU         VTMM         YOUT
       0.224937D+00 0.147735D+03 0.257828D+01 0.195241D+00 0.465387D-01

     VELOCITY FRACTIONAL DISPLACEMENT NORM = 0.712308D-04

 TEMPERATURE FRACTIONAL DISPLACEMENT NORM = 0.259812D-01     WALL TEMPERATURE = 0.548919D+03 'R


 TEMPERATURE ITERATION NUMBER  2

     VELOCITY ITERATION NUMBER  1

          DELT1        UDEL1        UTAU         VTMM         YOUT
       0.224894D+00 0.147735D+03 0.259744D+01 0.192166D+00 0.465299D-01

     VELOCITY FRACTIONAL DISPLACEMENT NORM = 0.755398D-03

     VELOCITY ITERATION NUMBER  2

          DELT1        UDEL1        UTAU         VTMM         YOUT
       0.224883D+00 0.147735D+03 0.258398D+01 0.195186D+00 0.465275D-01

     VELOCITY FRACTIONAL DISPLACEMENT NORM = 0.696440D-02

     VELOCITY ITERATION NUMBER  3

          DELT1        UDEL1        UTAU         VTMM         YOUT
       0.226088D+00 0.147735D+03 0.257678D+01 0.190532D+00 0.467768D-01

     VELOCITY FRACTIONAL DISPLACEMENT NORM = 0.221495D-02
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Figure B-2: A Sample Printout for Program Film (Page 7).

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     VELOCITY ITERATION NUMBER  4

           DELT1        UDEL1        UTAU         VTMM         YOUT
       0.227415D+00 0.147735D+03 0.257203D+01 0.194598D+00 0.470513D-01

     VELOCITY FRACTIONAL DISPLACEMENT NORM = 0.654340D-03

     VELOCITY ITERATION NUMBER  5

           DELT1        UDEL1        UTAU         VTMM         YOUT
       0.228099D+00 0.147735D+03 0.256981D+01 0.191879D+00 0.471929D-01

     VELOCITY FRACTIONAL DISPLACEMENT NORM = 0.170818D-03

     VELOCITY ITERATION NUMBER  6

           DELT1        UDEL1        UTAU         VTMM         YOUT
       0.228351D+00 0.147735D+03 0.256905D+01 0.195661D+00 0.472451D-01

     VELOCITY FRACTIONAL DISPLACEMENT NORM = 0.541138D-04

 TEMPERATURE FRACTIONAL DISPLACEMENT NORM = 0.561770D-02     WALL TEMPERATURE = 0.548842D+03 'R


 TEMPERATURE ITERATION NUMBER  3

     VELOCITY ITERATION NUMBER  1

           DELT1        UDEL1        UTAU         VTMM         YOUT
       0.228429D+00 0.147735D+03 0.256851D+01 0.192478D+00 0.472611D-01

     VELOCITY FRACTIONAL DISPLACEMENT NORM = 0.168534D-03

     VELOCITY ITERATION NUMBER  2

           DELT1        UDEL1        UTAU         VTMM         YOUT
       0.228449D+00 0.147735D+03 0.256901D+01 0.195525D+00 0.472654D-01

     VELOCITY FRACTIONAL DISPLACEMENT NORM = 0.148557D-02

     VELOCITY ITERATION NUMBER  3

           DELT1        UDEL1        UTAU         VTMM         YOUT
       0.227504D+00 0.147735D+03 0.256949D+01 0.193093D+00 0.470699D-01

     VELOCITY FRACTIONAL DISPLACEMENT NORM = 0.491565D-03

     VELOCITY ITERATION NUMBER  4

           DELT1        UDEL1        UTAU         VTMM         YOUT
       0.226920D+00 0.147735D+03 0.256996D+01 0.194558D+00 0.469498D-01

     VELOCITY FRACTIONAL DISPLACEMENT NORM = 0.122369D-03

     VELOCITY ITERATION NUMBER  5

           DELT1        UDEL1        UTAU         VTMM         YOUT
       0.226703D+00 0.147735D+03 0.257027D+01 0.192276D+00 0.469041D-01

     VELOCITY FRACTIONAL DISPLACEMENT NORM = 0.394601D-04

 TEMPERATURE FRACTIONAL DISPLACEMENT NORM = 0.119142D-02     WALL TEMPERATURE = 0.548859D+03 'R


 TEMPERATURE ITERATION NUMBER  4

     VELOCITY ITERATION NUMBER  1

           DELT1        UDEL1        UTAU         VTMM         YOUT
       0.226640D+00 0.147735D+03 0.257046D+01 0.193914D+00 0.468910D-01

     VELOCITY FRACTIONAL DISPLACEMENT NORM = 0.451438D-04

 TEMPERATURE FRACTIONAL DISPLACEMENT NORM = 0.177949D-03     WALL TEMPERATURE = 0.548858D+03 'R


 TEMPERATURE ITERATION NUMBER  5

     VELOCITY ITERATION NUMBER  1

           DELT1        UDEL1        UTAU         VTMM         YOUT
       0.226624D+00 0.147735D+03 0.257041D+01 0.192183D+00 0.468877D-01

     VELOCITY FRACTIONAL DISPLACEMENT NORM = 0.307978D-03
```

Figure B-2: A Sample Printout for Program Film (Page 8).

VELOCITY ITERATION NUMBER 2

DELT1	UDEL1	UTAU	VTMM	YOUT
0.226917D+00	0.147735D+03	0.257035D+01	0.193926D+00	0.469483D-01

VELOCITY FRACTIONAL DISPLACEMENT NORM = 0.606446D-04

TEMPERATURE FRACTIONAL DISPLACEMENT NORM = 0.299695D-04   WALL TEMPERATURE = 0.548857D+03 'R

TRANSVERSE DISTRIBUTION OF TEMPERATURE

Y (INCHES) TEMPERATURE T ('R)

0.0	*	0.548860D+03	0.548450D+03	0.548050D+03	0.547660D+03	0.547270D+03	0.546890D+03	0.546540D+03	0.546200D+03	0.545890D+03	0.545610D+03
0.0075	*	0.545360D+03	0.545140D+03	0.544950D+03	0.544780D+03	0.544640D+03	0.544520D+03	0.544420D+03	0.544350D+03	0.544290D+03	0.544260D+03
0.0150	*	0.544240D+03	0.544230D+03	0.544240D+03	0.544260D+03	0.544290D+03	0.5443[illegible]D+03	0.544380D+03	0.544440D+03	0.544510D+03	0.544590D+03
0.0225	*	0.544680D+03	0.544770D+03	0.544870D+03	0.544980D+03	0.545090D+03	0.545210D+03	0.545330D+03	0.545460D+03	0.545590D+03	0.545730D+03
0.0300	*	0.545870D+03	0.546010D+03	0.546160D+03	0.546320D+03	0.546470D+03	0.546630D+03	0.546800D+03	0.546960D+03	0.547130D+03	0.547300D+03
0.0375	*	0.547480D+03	0.547660D+03	0.547840D+03	0.548020D+03	0.548210D+03	0.548390D+03	0.548580D+03	0.548780D+03	0.548970D+03	0.549170D+03
0.0450	*	0.549370D+03	0.549570D+03	0.549770D+03	0.549980D+03	0.550180D+03	0.550390D+03	0.550600D+03	0.550820D+03	0.551030D+03	0.551250D+03
0.0525	*	0.551460D+03	0.551680D+03	0.551900D+03	0.552130D+03	0.552350D+03	0.552580D+03	0.552810D+03	0.553040D+03	0.553270D+03	0.553500D+03
0.0600	*	0.553730D+03	0.553970D+03	0.554200D+03	0.554440D+03	0.554680D+03	0.554920D+03	0.555170D+03	0.555410D+03	0.555650D+03	0.555900D+03
0.0675	*	0.556150D+03	0.556400D+03	0.556650D+03	0.556900D+03	0.557150D+03	0.557410D+03	0.557660D+03	0.557920D+03	0.558170D+03	0.558430D+03
0.0750	*	0.558690D+03	0.558950D+03	0.559220D+03	0.559480D+03	0.559740D+03	0.560010D+03	0.560280D+03	0.560540D+03	0.560810D+03	0.561080D+03
0.0825	*	0.561350D+03	0.561630D+03	0.561900D+03	0.562170D+03	0.562450D+03	0.562730D+03	0.563000D+03	0.563280D+03	0.563560D+03	0.563840D+03
0.0900	*	0.564120D+03	0.564400D+03	0.564690D+03	0.564970D+03	0.565250D+03	0.565540D+03	0.565830D+03	0.566110D+03	0.566400D+03	0.566690D+03
0.0975	*	0.566980D+03	0.567270D+03	0.567560D+03	0.567860D+03	0.568150D+03	0.568440D+03	0.568740D+03	0.569040D+03	0.569330D+03	0.569630D+03
0.1050	*	0.569930D+03	0.570230D+03	0.570530D+03	0.570830D+03	0.571130D+03	0.571430D+03	0.571730D+03	0.572040D+03	0.572340D+03	0.572650D+03
0.1125	*	0.572950D+03	0.573260D+03	0.573570D+03	0.573870D+03	0.574180D+03	0.574490D+03	0.574800D+03	0.575110D+03	0.575420D+03	0.575730D+03
0.1200	*	0.576050D+03	0.576360D+03	0.576670D+03	0.576990D+03	0.577300D+03	0.577620D+03	0.577930D+03	0.578250D+03	0.578570D+03	0.578890D+03
0.1275	*	0.579210D+03	0.579520D+03	0.579840D+03	0.580160D+03	0.580480D+03	0.580810D+03	0.581130D+03	0.581450D+03	0.581770D+03	0.582100D+03
0.1350	*	0.582420D+03	0.582740D+03	0.583070D+03	0.583390D+03	0.583720D+03	0.584050D+03	0.584370D+03	0.584700D+03	0.585030D+03	0.585360D+03
0.1425	*	0.585680D+03	0.586010D+03	0.586340D+03	0.586670D+03	0.587000D+03	0.587330D+03	0.587670D+03	0.588000D+03	0.588330D+03	0.588660D+03
0.1500	*	0.588990D+03	0.589330D+03	0.589660D+03	0.589990D+03	0.590330D+03	0.590660D+03	0.591000D+03	0.591330D+03	0.591670D+03	0.592010D+03
0.1575	*	0.592340D+03	0.592680D+03	0.593020D+03	0.593350D+03	0.593690D+03	0.594030D+03	0.594370D+03	0.594710D+03	0.595050D+03	0.595380D+03
0.1650	*	0.595720D+03	0.596060D+03	0.596400D+03	0.596740D+03	0.597090D+03	0.597430D+03	0.597770D+03	0.598110D+03	0.598450D+03	0.598790D+03
0.1725	*	0.599130D+03	0.599480D+03	0.599820D+03	0.600160D+03	0.600510D+03	0.600850D+03	0.601190D+03	0.601540D+03	0.601880D+03	0.602230D+03
0.1800	*	0.602570D+03	0.602910D+03	0.603260D+03	0.603600D+03	0.603950D+03	0.604290D+03	0.604640D+03	0.604990D+03	0.605330D+03	0.605680D+03
0.1875	*	0.606020D+03	0.606370D+03	0.606720D+03	0.607060D+03	0.607410D+03	0.607760D+03	0.608110D+03	0.608450D+03	0.608800D+03	0.609150D+03
0.1950	*	0.609500D+03	0.609840D+03	0.610190D+03	0.610540D+03	0.610890D+03	0.611240D+03	0.611580D+03	0.611930D+03	0.612280D+03	0.612630D+03
0.2025	*	0.612980D+03	0.613330D+03	0.613680D+03	0.614020D+03	0.614370D+03	0.614720D+03	0.615070D+03	0.615420D+03	0.615770D+03	0.616120D+03
0.2100	*	0.616470D+03	0.616820D+03	0.617170D+03	0.617520D+03	0.617870D+03	0.618220D+03	0.618570D+03	0.618920D+03	0.619270D+03	0.619620D+03
0.2175	*	0.619970D+03	0.620320D+03	0.620670D+03	0.621020D+03	0.621370D+03	0.621720D+03	0.622070D+03	0.622420D+03	0.622770D+03	0.623120D+03
0.2250	*	0.623470D+03	0.623820D+03	0.624170D+03	0.624520D+03	0.624870D+03	0.625220D+03	0.625570D+03	0.625920D+03	0.626260D+03	0.626610D+03
0.2325	*	0.626960D+03	0.627310D+03	0.627660D+03	0.628010D+03	0.628360D+03	0.628710D+03	0.629060D+03	0.629410D+03	0.629760D+03	0.630110D+03
0.2400	*	0.630460D+03	0.630810D+03	0.631160D+03	0.631510D+03	0.631860D+03	0.632200D+03	0.632550D+03	0.632900D+03	0.633250D+03	0.633600D+03
0.2475	*	0.633950D+03	0.634300D+03	0.634650D+03	0.634990D+03	0.635340D+03	0.635690D+03	0.636040D+03	0.636390D+03	0.636730D+03	0.637080D+03
0.2550	*	0.637430D+03	0.637780D+03	0.638120D+03	0.638470D+03	0.638820D+03	0.639170D+03	0.639510D+03	0.639860D+03	0.640210D+03	0.640550D+03
0.2625	*	0.640900D+03	0.641250D+03	0.641590D+03	0.641940D+03	0.642290D+03	0.642630D+03	0.642980D+03	0.643320D+03	0.643670D+03	0.644010D+03
0.2700	*	0.644360D+03	0.644700D+03	0.645050D+03	0.645390D+03	0.645740D+03	0.646080D+03	0.646430D+03	0.646770D+03	0.647110D+03	0.647460D+03
0.2775	*	0.647800D+03	0.648150D+03	0.648490D+03	0.648830D+03	0.649170D+03	0.649520D+03	0.649860D+03	0.650200D+03	0.650550D+03	0.650890D+03
0.2850	*	0.651230D+03	0.651570D+03	0.651910D+03	0.652260D+03	0.652600D+03	0.652940D+03	0.653280D+03	0.653620D+03	0.653960D+03	0.654300D+03
0.2925	*	0.654640D+03	0.654990D+03	0.655330D+03	0.655670D+03	0.656010D+03	0.656350D+03	0.656690D+03	0.657030D+03	0.657360D+03	0.657700D+03
0.3000	*	0.658040D+03	0.658380D+03	0.658720D+03	0.659060D+03	0.659400D+03	0.659740D+03	0.660070D+03	0.660410D+03	0.660750D+03	0.661090D+03
0.3075	*	0.661430D+03	0.661760D+03	0.662100D+03	0.662440D+03	0.662770D+03	0.663110D+03	0.663440D+03	0.663780D+03	0.664120D+03	0.664450D+03
0.3150	*	0.664790D+03	0.665120D+03	0.665460D+03	0.665790D+03	0.666120D+03	0.666460D+03	0.666790D+03	0.667130D+03	0.667460D+03	0.667790D+03
0.3225	*	0.668120D+03	0.668460D+03	0.668790D+03	0.669120D+03	0.669450D+03	0.669780D+03	0.670110D+03	0.670440D+03	0.670770D+03	0.671100D+03
0.3300	*	0.671430D+03	0.671760D+03	0.672090D+03	0.672420D+03	0.672740D+03	0.673070D+03	0.673400D+03	0.673730D+03	0.674050D+03	0.674380D+03
0.3375	*	0.674710D+03	0.675030D+03	0.675360D+03	0.675680D+03	0.676010D+03	0.676330D+03	0.676650D+03	0.676980D+03	0.677300D+03	0.677630D+03
0.3450	*	0.677950D+03	0.678270D+03	0.678590D+03	0.678920D+03	0.679240D+03	0.679560D+03	0.679880D+03	0.680210D+03	0.680530D+03	0.680850D+03
0.3525	*	0.681170D+03	0.681490D+03	0.681810D+03	0.682130D+03	0.682450D+03	0.682770D+03	0.683090D+03	0.683410D+03	0.683730D+03	0.684050D+03
0.3600	*	0.684370D+03	0.684690D+03	0.685010D+03	0.685330D+03	0.685650D+03	0.685970D+03	0.686290D+03	0.686610D+03	0.686930D+03	0.687250D+03
0.3675	*	0.687560D+03	0.687880D+03	0.688200D+03	0.688520D+03	0.688830D+03	0.689150D+03	0.689470D+03	0.689780D+03	0.690100D+03	0.690410D+03
0.3750	*	0.690730D+03	0.693880D+03	0.697000D+03	0.700080D+03	0.703140D+03	0.706170D+03	0.709170D+03	0.712140D+03	0.715080D+03	0.717990D+03
0.4500	*	0.720870D+03	0.723730D+03	0.726560D+03	0.729360D+03	0.732140D+03	0.734890D+03	0.737610D+03	0.740310D+03	0.742980D+03	0.745630D+03
0.5250	*	0.748250D+03	0.750840D+03	0.753400D+03	0.755940D+03	0.758440D+03	0.760900D+03	0.763350D+03	0.765800D+03	0.768260D+03	0.770720D+03
0.6000	*	0.773190D+03	0.775670D+03	0.778160D+03	0.780650D+03	0.783150D+03	0.785660D+03	0.788170D+03	0.790680D+03	0.793200D+03	0.795720D+03
0.6750	*	0.798240D+03	0.800760D+03	0.803280D+03	0.805800D+03	0.808320D+03	0.810840D+03	0.813360D+03	0.815880D+03	0.818390D+03	0.820910D+03
0.7500	*	0.823420D+03	0.825920D+03	0.828430D+03	0.830930D+03	0.833420D+03	0.835910D+03	0.838400D+03	0.840880D+03	0.843360D+03	0.845830D+03
0.8250	*	0.848290D+03	0.850750D+03	0.853210D+03	0.855650D+03	0.858090D+03	0.860520D+03	0.862940D+03	0.865350D+03	0.867760D+03	0.870150D+03
0.9000	*	0.872540D+03	0.874920D+03	0.877280D+03	0.879640D+03	0.881990D+03	0.884320D+03	0.886650D+03	0.888960D+03	0.891260D+03	0.893540D+03
0.9750	*	0.895830D+03	0.898100D+03	0.900350D+03	0.902590D+03	0.904820D+03	0.907030D+03	0.909230D+03	0.911420D+03	0.913590D+03	0.915740D+03
1.0500	*	0.917890D+03	0.920010D+03	0.922120D+03	0.924220D+03	0.926290D+03	0.928350D+03	0.930400D+03	0.932430D+03	0.934440D+03	0.936430D+03
1.1250	*	0.938400D+03	0.940360D+03	0.942300D+03	0.944220D+03	0.946120D+03	0.948000D+03	0.949870D+03	0.951710D+03	0.953530D+03	0.955340D+03
1.2000	*	0.957120D+03	0.958880D+03	0.960630D+03	0.962350D+03	0.964050D+03	0.965730D+03	0.967390D+03	0.969030D+03	0.970650D+03	0.972250D+03
1.2750	*	0.973820D+03	0.975370D+03	0.976910D+03	0.978420D+03	0.979910D+03	0.981370D+03	0.982820D+03	0.984240D+03	0.985640D+03	0.987020D+03
1.3500	*	0.988380D+03	0.989710D+03	0.991[illegible]D+03	0.992320D+03	0.993590D+03	0.994840D+03	0.996070D+03	0.997270D+03	0.998450D+03	0.999620D+03
1.4250	*	0.100080D+04	0.100190D+04	0.100300D+04	0.100400D+04	0.100510D+04	0.100610D+04	0.100720D+04	0.100810D+04	0.100910D+04	0.101010D+04
1.5000	*	0.101100D+04	0.102030D+04	0.102750D+04	0.103360D+04	0.103810D+04	0.104130D+04	0.104370D+04	0.104530D+04	0.104640D+04	0.104700D+04
2.2500	*	0.104750D+04	0.104770D+04	0.104780D+04	0.104790D+04	0.104800D+04	0.104800D+04	0.104800D+04	0.104800D+04	0.104800D+04	0.104800D+04
3.0000	*	0.104800D+04	0.104800D+04	0.104800D+04	0.104800D+04	0.104800D+04	0.104800D+04	0.104800D+04	0.104800D+04	0.104800D+04	0.104800D+04
3.7500	*	0.104800D+04	0.104800D+04	0.104800D+04	0.104800D+04	0.104800D+04	0.104800D+04	0.104800D+04	0.104800D+04	0.104800D+04	0.104800D+04
4.5000	*	0.104800D+04	0.104800D+04	0.104800D+04	0.104800D+04	0.104800D+04	0.104800D+04	0.104800D+04	0.104800D+04	0.104800D+04	0.104800D+04
5.2500	*	0.104800D+04									

TRANSVERSE DISTRIBUTION OF STREAMWISE VELOCITY

Y (INCHES) VELOCITY U (FPS)

0.0	*	0.0	0.215480D+01	0.431700D+01	0.647790D+01	0.861700D+01	0.107020D+02	0.126940D+02	0.145600D+02	0.162790D+02	0.178450D+02
0.0075	*	0.192620D+02	0.205410D+02	0.216970D+02	0.227440D+02	0.236950D+02	0.245610D+02	0.253540D+02	0.260830D+02	0.267550D+02	0.273770D+02
0.0150	*	0.279550D+02	0.284940D+02	0.289980D+02	0.294720D+02	0.299170D+02	0.303370D+02	0.307340D+02	0.311110D+02	0.314690D+02	0.318100D+02
0.0225	*	0.321360D+02	0.324470D+02	0.327450D+02	0.330300D+02	0.333050D+02	0.335690D+02	0.338240D+02	0.340690D+02	0.343070D+02	0.345360D+02
0.0300	*	0.347580D+02	0.349740D+02	0.351830D+02	0.353860D+02	0.355830D+02	0.357750D+02	0.359620D+02	0.361450D+02	0.363230D+02	0.364960D+02
0.0375	*	0.366660D+02	0.368320D+02	0.369940D+02	0.371520D+02	0.373080D+02	0.374600D+02	0.376090D+02	0.377560D+02	0.379000D+02	0.380410D+02

Figure B-2: A Sample Printout for Program Film (Page 9).

0.0450	0.38179D+02	0.38316D+02	0.38449D+02	0.38581D+02	0.38711D+02	0.38839D+02	0.38964D+02	0.39088D+02	0.39210D+02	0.39330D+02
0.0525	0.39449D+02	0.39566D+02	0.39681D+02	0.39795D+02	0.39908D+02	0.40019D+02	0.40129D+02	0.40237D+02	0.40344D+02	0.40450D+02
0.0600	0.40555D+02	0.40659D+02	0.40761D+02	0.40863D+02	0.40963D+02	0.41062D+02	0.41161D+02	0.41258D+02	0.41355D+02	0.41450D+02
0.0675	0.41545D+02	0.41639D+02	0.41732D+02	0.41824D+02	0.41915D+02	0.42006D+02	0.42096D+02	0.42185D+02	0.42273D+02	0.42361D+02
0.0750	0.42448D+02	0.42534D+02	0.42620D+02	0.42705D+02	0.42789D+02	0.42873D+02	0.42956D+02	0.43039D+02	0.43121D+02	0.43202D+02
0.0825	0.43283D+02	0.43364D+02	0.43444D+02	0.43523D+02	0.43602D+02	0.43680D+02	0.43758D+02	0.43836D+02	0.43912D+02	0.43989D+02
0.0900	0.44065D+02	0.44141D+02	0.44216D+02	0.44291D+02	0.44365D+02	0.44439D+02	0.44513D+02	0.44586D+02	0.44659D+02	0.44731D+02
0.0975	0.44803D+02	0.44875D+02	0.44946D+02	0.45017D+02	0.45088D+02	0.45156D+02	0.45228D+02	0.45298D+02	0.45367D+02	0.45436D+02
0.1050	0.45505D+02	0.45573D+02	0.45641D+02	0.45709D+02	0.45776D+02	0.45843D+02	0.45910D+02	0.45977D+02	0.46043D+02	0.46109D+02
0.1125	0.46175D+02	0.46241D+02	0.46306D+02	0.46371D+02	0.46435D+02	0.46500D+02	0.46564D+02	0.46628D+02	0.46692D+02	0.46755D+02
0.1200	0.46819D+02	0.46882D+02	0.46944D+02	0.47007D+02	0.47069D+02	0.47132D+02	0.47193D+02	0.47255D+02	0.47317D+02	0.47378D+02
0.1275	0.47439D+02	0.47500D+02	0.47560D+02	0.47621D+02	0.47681D+02	0.47741D+02	0.47801D+02	0.47861D+02	0.47920D+02	0.47979D+02
0.1350	0.48039D+02	0.48097D+02	0.48156D+02	0.48215D+02	0.48273D+02	0.48331D+02	0.48389D+02	0.48447D+02	0.48505D+02	0.48562D+02
0.1425	0.48620D+02	0.48677D+02	0.48734D+02	0.48791D+02	0.48847D+02	0.48904D+02	0.48960D+02	0.49017D+02	0.49073D+02	0.49129D+02
0.1500	0.49184D+02	0.49240D+02	0.49295D+02	0.49351D+02	0.49406D+02	0.49461D+02	0.49516D+02	0.49571D+02	0.49625D+02	0.49680D+02
0.1575	0.49734D+02	0.49788D+02	0.49842D+02	0.49896D+02	0.49950D+02	0.50004D+02	0.50057D+02	0.50110D+02	0.50164D+02	0.50217D+02
0.1650	0.50270D+02	0.50323D+02	0.50375D+02	0.50428D+02	0.50481D+02	0.50533D+02	0.50585D+02	0.50637D+02	0.50689D+02	0.50741D+02
0.1725	0.50793D+02	0.50845D+02	0.50896D+02	0.50948D+02	0.50999D+02	0.51050D+02	0.51102D+02	0.51153D+02	0.51203D+02	0.51254D+02
0.1800	0.51305D+02	0.51355D+02	0.51406D+02	0.51456D+02	0.51507D+02	0.51557D+02	0.51607D+02	0.51657D+02	0.51707D+02	0.51756D+02
0.1875	0.51806D+02	0.51855D+02	0.51905D+02	0.51954D+02	0.52003D+02	0.52053D+02	0.52102D+02	0.52151D+02	0.52199D+02	0.52248D+02
0.1950	0.52297D+02	0.52345D+02	0.52394D+02	0.52442D+02	0.52491D+02	0.52539D+02	0.52587D+02	0.52635D+02	0.52683D+02	0.52731D+02
0.2025	0.52779D+02	0.52826D+02	0.52874D+02	0.52921D+02	0.52969D+02	0.53016D+02	0.53063D+02	0.53110D+02	0.53158D+02	0.53205D+02
0.2100	0.53251D+02	0.53298D+02	0.53345D+02	0.53392D+02	0.53438D+02	0.53485D+02	0.53531D+02	0.53578D+02	0.53624D+02	0.53670D+02
0.2175	0.53716D+02	0.53762D+02	0.53808D+02	0.53854D+02	0.53900D+02	0.53946D+02	0.53991D+02	0.54037D+02	0.54082D+02	0.54128D+02
0.2250	0.54173D+02	0.54218D+02	0.54264D+02	0.54309D+02	0.54354D+02	0.54399D+02	0.54444D+02	0.54489D+02	0.54533D+02	0.54578D+02
0.2325	0.54623D+02	0.54667D+02	0.54712D+02	0.54756D+02	0.54801D+02	0.54845D+02	0.54889D+02	0.54933D+02	0.54977D+02	0.55021D+02
0.2400	0.55065D+02	0.55109D+02	0.55153D+02	0.55197D+02	0.55240D+02	0.55284D+02	0.55328D+02	0.55371D+02	0.55414D+02	0.55458D+02
0.2475	0.55501D+02	0.55544D+02	0.55588D+02	0.55631D+02	0.55674D+02	0.55717D+02	0.55760D+02	0.55802D+02	0.55845D+02	0.55888D+02
0.2550	0.55931D+02	0.55973D+02	0.56016D+02	0.56058D+02	0.56101D+02	0.56143D+02	0.56185D+02	0.56228D+02	0.56270D+02	0.56312D+02
0.2625	0.56354D+02	0.56396D+02	0.56438D+02	0.56480D+02	0.56522D+02	0.56564D+02	0.56605D+02	0.56647D+02	0.56689D+02	0.56730D+02
0.2700	0.56772D+02	0.56813D+02	0.56855D+02	0.56896D+02	0.56937D+02	0.56978D+02	0.57020D+02	0.57061D+02	0.57102D+02	0.57143D+02
0.2775	0.57184D+02	0.57225D+02	0.57265D+02	0.57306D+02	0.57347D+02	0.57388D+02	0.57428D+02	0.57469D+02	0.57510D+02	0.57550D+02
0.2850	0.57590D+02	0.57631D+02	0.57671D+02	0.57712D+02	0.57752D+02	0.57792D+02	0.57832D+02	0.57872D+02	0.57912D+02	0.57952D+02
0.2925	0.57992D+02	0.58032D+02	0.58072D+02	0.58112D+02	0.58152D+02	0.58192D+02	0.58231D+02	0.58271D+02	0.58311D+02	0.58350D+02
0.3000	0.58390D+02	0.58429D+02	0.58469D+02	0.58508D+02	0.58548D+02	0.58587D+02	0.58626D+02	0.58665D+02	0.58705D+02	0.58744D+02
0.3075	0.58783D+02	0.58822D+02	0.58861D+02	0.58900D+02	0.58939D+02	0.58978D+02	0.59016D+02	0.59055D+02	0.59094D+02	0.59133D+02
0.3150	0.59171D+02	0.59210D+02	0.59248D+02	0.59287D+02	0.59325D+02	0.59364D+02	0.59402D+02	0.59440D+02	0.59479D+02	0.59517D+02
0.3225	0.59555D+02	0.59593D+02	0.59631D+02	0.59669D+02	0.59707D+02	0.59745D+02	0.59783D+02	0.59820D+02	0.59858D+02	0.59896D+02
0.3300	0.59934D+02	0.59971D+02	0.60009D+02	0.60046D+02	0.60084D+02	0.60121D+02	0.60158D+02	0.60195D+02	0.60233D+02	0.60270D+02
0.3375	0.60307D+02	0.60344D+02	0.60381D+02	0.60418D+02	0.60455D+02	0.60492D+02	0.60529D+02	0.60566D+02	0.60602D+02	0.60639D+02
0.3450	0.60676D+02	0.60712D+02	0.60749D+02	0.60786D+02	0.60822D+02	0.60859D+02	0.60895D+02	0.60932D+02	0.60968D+02	0.61004D+02
0.3525	0.61041D+02	0.61077D+02	0.61113D+02	0.61150D+02	0.61186D+02	0.61222D+02	0.61259D+02	0.61295D+02	0.61331D+02	0.61367D+02
0.3600	0.61403D+02	0.61439D+02	0.61475D+02	0.61512D+02	0.61548D+02	0.61584D+02	0.61620D+02	0.61656D+02	0.61692D+02	0.61727D+02
0.3675	0.61763D+02	0.61799D+02	0.61835D+02	0.61871D+02	0.61906D+02	0.61942D+02	0.61978D+02	0.62013D+02	0.62049D+02	0.62084D+02
0.3750	0.62120D+02	0.62475D+02	0.62825D+02	0.63173D+02	0.63516D+02	0.63857D+02	0.64194D+02	0.64529D+02	0.64860D+02	0.65188D+02
0.4500	0.65514D+02	0.65837D+02	0.66157D+02	0.66475D+02	0.66790D+02	0.67104D+02	0.67415D+02	0.67724D+02	0.68031D+02	0.68335D+02
0.5250	0.68638D+02	0.68938D+02	0.69235D+02	0.69530D+02	0.69822D+02	0.70111D+02	0.70399D+02	0.70688D+02	0.70979D+02	0.71271D+02
0.6000	0.71566D+02	0.71863D+02	0.72162D+02	0.72462D+02	0.72765D+02	0.73070D+02	0.73377D+02	0.73685D+02	0.73995D+02	0.74307D+02
0.6750	0.74620D+02	0.74935D+02	0.75251D+02	0.75569D+02	0.75888D+02	0.76209D+02	0.76531D+02	0.76854D+02	0.77179D+02	0.77505D+02
0.7500	0.77833D+02	0.78162D+02	0.78492D+02	0.78823D+02	0.79156D+02	0.79491D+02	0.79826D+02	0.80163D+02	0.80501D+02	0.80841D+02
0.8250	0.81181D+02	0.81523D+02	0.81866D+02	0.82210D+02	0.82555D+02	0.82902D+02	0.83249D+02	0.83598D+02	0.83947D+02	0.84298D+02
0.9000	0.84650D+02	0.85002D+02	0.85356D+02	0.85710D+02	0.86066D+02	0.86422D+02	0.86779D+02	0.87137D+02	0.87496D+02	0.87856D+02
0.9750	0.88216D+02	0.88578D+02	0.88940D+02	0.89303D+02	0.89666D+02	0.90030D+02	0.90395D+02	0.90761D+02	0.91127D+02	0.91493D+02
1.0500	0.91861D+02	0.92228D+02	0.92597D+02	0.92966D+02	0.93335D+02	0.93705D+02	0.94075D+02	0.94446D+02	0.94817D+02	0.95188D+02
1.1250	0.95560D+02	0.95932D+02	0.96304D+02	0.96677D+02	0.97050D+02	0.97423D+02	0.97796D+02	0.98169D+02	0.98543D+02	0.98916D+02
1.2000	0.99290D+02	0.99664D+02	0.10004D+03	0.10041D+03	0.10079D+03	0.10116D+03	0.10153D+03	0.10191D+03	0.10228D+03	0.10265D+03
1.2750	0.10303D+03	0.10340D+03	0.10377D+03	0.10414D+03	0.10452D+03	0.10489D+03	0.10526D+03	0.10563D+03	0.10600D+03	0.10637D+03
1.3500	0.10674D+03	0.10711D+03	0.10748D+03	0.10784D+03	0.10821D+03	0.10858D+03	0.10894D+03	0.10931D+03	0.10967D+03	0.11003D+03
1.4250	0.11040D+03	0.11076D+03	0.11112D+03	0.11148D+03	0.11184D+03	0.11220D+03	0.11255D+03	0.11291D+03	0.11326D+03	0.11362D+03
1.5000	0.11397D+03	0.11749D+03	0.12086D+03	0.12404D+03	0.12704D+03	0.12982D+03	0.13237D+03	0.13471D+03	0.13683D+03	0.13874D+03
2.2500	0.14047D+03	0.14202D+03	0.14341D+03	0.14465D+03	0.14574D+03	0.14670D+03	0.14752D+03	0.14819D+03	0.14871D+03	0.14906D+03
3.0000	0.14921D+03	0.14924D+03	0.14924D+03	0.14924D+03	0.14924D+03	0.14924D+03	0.14924D+03	0.14924D+03	0.14924D+03	0.14924D+03
3.7500	0.14924D+03	0.14924D+03	0.14924D+03	0.14924D+03	0.14924D+03	0.14924D+03	0.14924D+03	0.14924D+03	0.14924D+03	0.14924D+03
4.5000	0.14924D+03	0.14924D+03	0.14924D+03	0.14924D+03	0.14924D+03	0.14924D+03	0.14924D+03	0.14924D+03	0.14924D+03	0.14925D+03
5.2500	0.14923D+03									

Figure B-2: A Sample Printout for Program Film (Page 10).

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DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall document is classified)

1. ORIGINATING ACTIVITY DEFENCE RESEARCH ESTABLISHMENT SUFFIELD	2a. DOCUMENT SECURITY CLASSIFICATION UNCLASSIFIED 2b. GROUP

3. DOCUMENT TITLE

A CALCULATION METHOD FOR CONVECTIVE HEAT AND MASS TRANSFER IN MULTIPLY-SLOTTED FILM-COOLING APPLICATIONS (U)

4. DESCRIPTIVE NOTES (Type of report and inclusive dates) Technical Paper

5. AUTHOR(S) (Last name, first name, middle initial)

Murray, S.B.

6. DOCUMENT DATE JANUARY 1980	7a. TOTAL NO. OF PAGES 85	7b. NO. OF REFS 13
8a. PROJECT OR GRANT NO. PCN 27C02 TASK DMFR 14	9a. ORIGINATOR'S DOCUMENT NUMBER(S) SUFFIELD TECHNICAL PAPER NO. 507	
8b. CONTRACT NO.	9b. OTHER DOCUMENT NO.(S) (Any other numbers that may be assigned this document)	

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13. ABSTRACT

A computer model to calculate the development of wall jet boundary layers downstream of multiple film-cooling slots is described. The differential equations for the conservation of mass, momentum and energy in an incompressible two-dimensional or axisymmetric flow are solved using a downstream-marching, iterative, implicit, finite-difference scheme. The turbulent transport of mass in a conventional wall boundary layer is described by means of an inner-outer two-layer eddy-viscosity model based on the Prandtl mixing-length hypothesis with Van Driest's modification in the near-wall region. Further alterations to include the effects of pressure gradients, heat and mass transfer are due to Cebeci and Smith. This basic model is extended to include cases with tangential fluid injection.

Computed velocity profiles indicate that the law of the wall is obeyed in the inner layer and that the outer wake-like layer strives to resume the velocity-defect relationship that existed upstream of the point of fluid injection in zero pressure-gradient flow with no heat or mass transfer.

Comparison between computed and experimental adiabatic wall temperature distributions in flows with heat transfer shows that the eddy-viscosity model is deficient in the near-slot region and tends to

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ABSTRACT (Cont'd)

overestimate film-cooling efficiency. The absence of an eddy term to account for turbulence due to finite slot lip thickness is partly responsible for this overestimation.

Recommendations are made to validate the model in pressure-gradient flows and to improve the predictive capability in the near-slot region. (U)

Turbulent Boundary Layers
Turbulent Mixing
Eddy-Viscosity Model
Mixing Model
Wall Cooling
Fluid Injection
Numerical Calculations
Convective Heat and Mass Transfer
Reynolds Stress Model
Wall Jets
Film Cooling